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THE ECONOMICS OF CLEAN WATER. VOLUME 3. INORGANIC CHEMICALS INDUSTRY PROFILE

Federal Water Pollution Control Administration
Washington, D. C.

March 1970

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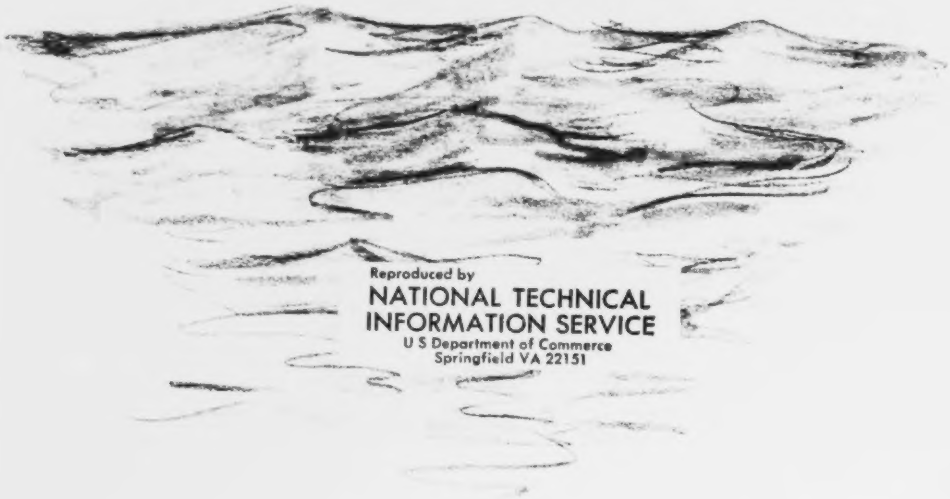
THE ECONOMICS OF CLEAN WATER



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CLEAN
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THE ECONOMICS OF CLEAN WATER

VOLUME III

Inorganic Chemicals Industry Profile

Prepared Under Contract No. 14-12-592

MARCH 3, 1849

U. S. Department of the Interior
Federal Water Pollution Control Administration
March 1970

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March 3, 1849

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

APR 3 1970

Dear Mr. President:

I am transmitting to the Congress the third report on the national requirements and cost of water pollution control as required under Section 16 (a) of the Federal Water Pollution Control Act, as amended.

The decade of the 1970's, a decade which will address itself to improving the quality of man's environment, will see great strides toward the effort to abate water pollution. The enclosed report entitled "The Economics of Clean Water" represents our current estimates of the investment levels necessary to attain applicable water quality standards.

This report, along with the two previously submitted, contributes to closing the information gap in terms of the overall magnitude, geographical, and financial dimensions, all of which are essential to the development of national policies and programs directed toward achieving water quality standards in an efficient and effective manner.

The alternatives analyzed in the course of this study, especially those aspects contained in Volume I, presented valuable background for development of proposals on aid to municipal treatment works presented to the Congress in the President's Environmental Message and subsequent legislation.

There are four parts to this year's report. The first is a summary of major findings and conclusions of the analysis. The second, Volume I, contains the details of the analysis. The third, Volume II, is a profile of animal wastes. The fourth and last section, Volume III, is an industrial profile of the inorganic chemicals industry.

Sincerely yours,

Walter J. Hickel

Secretary of the Interior

Hon. Spiro Agnew
President of the Senate
Washington, D. C. 20510

Enclosure

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OFFICE OF THE SECRETARY
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Hon. John W. McCormack
Speaker of the House of
Representatives
Washington, D. C. 20515

Enclosure

TABLE OF CONTENTS

Page

I. Summary.................................... 1

II. Introduction.............................. 7

III. The Inorganic Chemical Industry............. 8

IV. Projected Industry Growth.................. 15

V. Wastewater Characteristics................. 19

VI. Wastewater Treatment Methods............... 22

VII. Industrial Waste Treatment Practices Data Form...................................... 31

VIII. Plant Survey Data......................... 33

IX. Costs of Unit Wastewater Treatment Methods... 45

X. Costs Versus Effluent Quality Relationships.................................. 53

XI. Projected Industry Costs................... 55

XII. Qualitative Manpower Requirements........... 76

XIII. Quantitative Manpower Requirements.......... 97

TABLE OF CONTENTS (cont.)

APPENDIX

Page

A. Industrial Waste Treatment Practices Data Form........ 122

B. Inorganic Chemical Industry Survey Data...... 176

C. Inorganic Chemical Industry Product Profiles........ 178

D. Qualitative Personnel Requirements for Treatment Processes........ 245

E. Costs of Unit Wastewater Treatment Practices........ 397

F. Bibliography........ 459

LIST OF TABLES

Page

CHAPTER III - THE INORGANIC CHEMICAL INDUSTRY

Table I - Financial Ratios for the Industrial Chemical Industry.................................. 10

Table II - Value of Estimated Inorganic Chemical Shipments... 11

CHAPTER IV - PROJECTED INDUSTRY GROWTH

Table I - Production of Inorganic Chemicals....... 16

Table II - Industry Segmental Growth Rates Through 1979.................................... 17

Table III - Industry Growth Rates Geographically Through 1975.................................... 17

CHAPTER V - WASTEWATER CHARACTERISTICS

Table I - Composition of Typical Clean Water Effluent... 20

CHAPTER VI - WASTEWATER TREATMENT METHODS

Table I - Water Discharge by SIC.................. 26

Table II - Employment Distribution................ 27

Table III - Distribution of Water Use............. 28

CHAPTER IX - COSTS OF UNIT WASTEWATER TREATMENT METHODS

Table I - Treatment Level I, Neutralization Costs Including Equalization and Sludge Dewatering.... 50

Table II - Treatment Level II, Demineralization Costs Including Prefiltration and Brine Disposal... 51

LIST OF TABLES (cont.)

Page

CHAPTER XI - PROJECTED INDUSTRY COSTS

Table I - Numbers of Inorganic Chemical Plants by Water Intake Volume - 1963.................... 55

Table II - Water Discharges from Large Inorganic Chemical Plants - 1963........................ 55

Table III - Large Inorganic Chemical Plant Discharges Other Than to Municipal Sewers - 1963... 56

Table IV - Large Inorganic Chemical Plant Intakes and Usage, by Purpose, 1963.................. 57

Table V - The Inorganic Chemical Industry, 1958 and 1963.. 58

Table VI - Number of Plants and Value of Shipments, 1958 Prices................................ 59

Table VII - Values of Inorganic Chemical Shipments, 1966....................................... 59

Table VIII - Values of Inorganic Chemical Shipments, 1968 and 1969.............................. 60

Table IX - Numbers of Plants in the Inorganic Chemical Industry................................ 61

Table X - Numbers of Inorganic Chemical Plants for Study Purposes............................... 61

Table XI - Projected Production of Inorganic Chemicals, 1968-1974.............................. 63

Table XII - The Inorganic Chemical Industry, 1963-74... 64

Table XIII - Water Use Data, 1958-67............. 65

Table XIV - The Inorganic Chemical Industry, 1963-74... 67

LIST OF TABLES (cont.)

Page

CHAPTER XI (cont.)

Table XV - 1967 MCA Survey Data, The Chemical Industry.. 68

Table XVI - Ranges of Chemical Plant Production Capacities.................................... 69

Table XVII - Numbers of Plants in the Chemical Industry, 1963................................ 69

Table XVIII - Chemical Industry Survey Data, 1967.. 70

Table XIX - Chemical Plant Sizes and Discharges, 1967... 71

Table XX - Chemical Industry Discharges, 1967..... 72

Table XXI - Chemical Industry Costs and Manpower, 1969.. 72

Table XXII - Cumulative Inorganic Chemical Industry Capital Costs, 1969-1974............... 73

Table XXIII - Cumulative Inorganic Chemical Industry Capital Costs, 1969-1974............... 73

Table XXIV - Projected Annual Inorganic Chemical Industry Operating Costs....................... 74

Table XXV - Projected Annual Inorganic Chemical Industry Operating Costs....................... 74

CHAPTER XIII - QUANTITATIVE MANPOWER REQUIREMENTS

Table I - Equalization, man-hours/year............ 103

Table II - Chemical Addition, man-hours/year...... 105

Table III - Lagooning, man-hours/year............. 106

LIST OF TABLES (cont.)

Page

CHAPTER XIII (cont.)

Table IV - Sedimentation, man-hours/year.......... 108

Table V - Filtration, man-hours/year.............. 109

Table VI - Reverse Osmosis, man-hours/year........ 111

Table VII - Deep Well Injection, man-hours/year... 113

Table VIII - Large Plant, Level I Treatment-27% Removal, Equalization, Chemical Addition, Lagoon.. 114

Table IX - Large Plant, Level II Treatment-100% Removal, Equalization, Chemical Addition, Sedimentation, Filtration, Reverse Osmosis, Deep Well Injection............................ 115

Table X - Small Plant, Level I Treatment-27% Removal, Equalization, Chemical Addition, Lagoon, Total Effluent Assumed Discharged to Municipal Sewers... 116

Table XI - Number of Operator Personnel Assigned to Waste Treatment.............................. 117

Table XII - Assigned Plant Operators.............. 118

Table XIII - Number of Trained Wastewater Treatment Plant Operators Required....................... 120

APPENDIX B - INORGANIC CHEMICAL INDUSTRY SURVEY DATA

Table I.. 177

APPENDIX E - COSTS OF UNIT WASTEWATER TREATMENT PRACTICES

Table I.. 433

LIST OF FIGURES

Page

CHAPTER III - THE INORGANIC CHEMICAL INDUSTRY

Figure 1 - Location of Major Inorganic Chemical Plants, SIC Nos. 2812, 2816, 2819................ 14

CHAPTER VI - WASTEWATER TREATMENT METHODS

Figure 1 - Wastewater Treatment Sequence.......... 23

CHAPTER VIII - PLANT SURVEY DATA

Figure 1 - Total 1969 Production - Millions of Tons/Year.................................... 35

Figure 2 - Production - Thousands of Tons/Year.... 36

Figure 3 - Flow - MGD............................. 37

Figure 4 - Plant Employment...................... 38

Figure 5 - Major Source of Water................. 39

Figure 6 - Basis of Treatment Decision........... 40

Figure 7 - Year of Construction.................. 41

Figure 8 - States................................ 42

Figure 9 - Industry Water Use Regions............ 43

Figure 10 - Operating Costs of Treatment Facilities Versus Capital Costs.......................... 44

CHAPTER IX - COSTS OF UNIT WASTEWATER TREATMENT METHODS

Figure 1 - Applicable Ranges of Demineralization Units...................................... 46

LIST OF FIGURES (cont.)

Page

CHAPTER IX (cont.)

Figure 2 - Schematic Layout of Treatment Plant for Wastes from the Inorganic Chemical Industry Showing Various Possible Combinations of Units.. 47

Figure 3 - Flow Sheet for Neutralization Plant.... 48

CHAPTER XI - PROJECTED INDUSTRY COSTS

Figure 1 - No. of Plants Versus Value of Shipments.. 62

APPENDIX C - INORGANIC CHEMICAL INDUSTRY PRODUCT PROFILES

Figure 1 - Flowchart for Diaphragm Caustic Soda and Chlorine Cell................................ 182

Figure 2 - Flowchart of a Standard Medium-Pressure Air-Separation Plant.......................... 187

Figure 3 - Flowchart for Titanium Dioxide......... 192

Figure 4 - Flowchart for Mixing of Paint.......... 193

Figure 5 - Ammonium Nitrate Plant Locations....... 198

Figure 6 - Flowchart for 60% Nitric Acid from Ammonia.. 207

Figure 7 - Phosphoric Acid Plant Locations........ 211

Figure 8 - Typical Flowchart for Sulfur-Burning Contact Plant.................................. 223

Figure 9 - Ammonium Phosphate Plant Locations..... 230

Figure 10 - Estimated Number of Bulk Blend Fertilizer Plants............................. 234

LIST OF FIGURES (cont.)

Page

APPENDIX C (cont.)

Figure 11 - Estimated Number of Liquid Mixed Fertilizer Plants.............................. 236

Figure 12 - Flowchart for Smokeless Powder........ 243

APPENDIX E

Figure 1 - Applicable Ranges of Demineralization Units... 399

Figure 2 - Schematic Layout of Treatment Plant for Wastes from the Inorganic Chemical Industry Showing Various Possible Combinations of Units.. 400

Figure 3 - Flow Sheet for Neutralization Plant.... 402

Figure 4 - Cap. Cost of Neutralization Facilities Excluding Sludge Treatment..................... 403

Figure 5 - Cap. Cost Versus Acidity for 1 MGD Plant... 404

Figure 6 - Capital Cost of Equalization Basins.... 405

Figure 7 - Thickener Parameters for Sludge from Neutralization of Acidic Wastes................ 08

Figure 8 - Variation of K_B with Initial Solids Concentration................................. 409

Figure 9 - Capital Cost of Thickeners............ 412

Figure 10 - Operating Costs for Lime Neutralization Including Sludge Dewatering by Vacuum Filtration... 414

Figure 11 - Cost of Filtration Through Sand or Graded Media................................... 416

Figure 12 - Annual Operating Cost of Deep Well Injection Systems for Waste Disposal........... 418

LIST OF FIGURES (cont.)

Page

APPENDIX E (cont.)

Figure 13 - Capital Cost of Deep Well Injection Systems for Waste Disposal.................... 419

Figure 14 - Area of Membranes as a Function of Production Rate.................................. 421

Figure 15 - Membrane Area Required Versus Feed and Product Flows................................ 422

Figure 16 - Power Consumption as a Function of Production Rate.................................. 423

Figure 17 - Capital Cost as a Function of Production Rate.................................. 424

Figure 18 - Capital Cost of Reverse Osmosis Plant.. 426

Figure 19 - Operating Cost for Reverse Osmosis Plant.. 427

Figure 20 - Determination of Total Number of Units Required for Treatment.................. 429

Figure 21 - Relationship of Plate Area Required for a Desired TDS Removal...................... 430

Figure 22 - Relationship of Rectifier Size to Specific TDS Removal Desired.................. 431

Figure 23 - Capital Cost of Membranes, Spacers, End Plates, and Electrodes.................... 435

Figure 24 - Capital Cost Curves for DC Rectifier for Electrodialysis.......................... 436

Figure 25 - Relationship of DC Energy Required for a Desired TDS Removal........................ 437

Figure 26 - Operating Cost of DC Energy Required for Specific TDS Removal...................... 439

LIST OF FIGURES (cont.)

Page

APPENDIX E (cont.)

Figure 27 (capital and Operating Costs for Electrodialysis Based on Feed Flow to Plant at 3000 ppm TDS.................................... 440

Figure 28 - Capital Cost of Ion Exchange Plant.... 442

Figure 29 - Chemical Cost per Pound TDS Removed by Ion Exchange.......................... 443

Figure 30 - Capital and Operating Cost for Multiple Effect Evaporation..................... 446

Figure 31 - Vapor Pressure of Water Versus Temperature..................................... 448

Figure 32 - Evaporation Versus Vapor Pressure Differential.................................... 449

Figure 33 - Area Versus Required Evaporation...... 450

Figure 34 - Capital Cost Relationship for Lagoons... 451

Figure 35 - Relative Rating Factors Versus Wet Bulb Temperatures.............................. 456

Figure 36 - Cooling Towers....................... 458

CHAPTER I

SUMMARY

This report presents a description of the inorganic chemical industry, and the costs that the industry would incur in attaining various levels of pollution abatement over a five year period through 1974. Also presented is a description of the corresponding qualitative and quantitative manpower requirements for the operation and maintenance of the foregoing waste treatment facilities. The cost estimates have been based upon published data, general data derived from information in the files of the Contractors on industrial waste treatment methods and costs, and specific data from 59 inorganic chemical plants, some of which were supplied by the Manufacturing Chemists Association. (The data supplied by the M.C.A. were presented in such a manner as to render impossible identification of proprietary information relating to a specific plant's construction, operation, maintenance, or production.)

The inorganic chemical industry has been defined for purposes of this study as including establishments producing alkalies and chlorine, industrial gases, inorganic pigments, paints and allied products, fertilizers (excluding ammonia and urea), inorganic insecticides and herbicides, explosives, and other major industrial inorganic chemicals. The complex relationship which exists between various products and industries, however, make it extremely difficult to arbitrarily associate certain products with one category. The overall output of the industry, since its products are used for a wide variety of purposes well removed from the final consumer, depends upon the level of total economic activity rather than the economic activity in any one segment of the economy. Since new mineral sources are discovered infrequently and usually involve large development expenditures, wide fluctuations in the gap between demand and readily available supply are quite common.

Total production in the inorganic chemical industry is estimated to be 328.7 billion pounds in 1969 and projected at 455.5 billion pounds in 1974. While certain segments of the industry are growing as rapidly as 18% per year, the historical situation is for a growth rate 1.5 to 2.0 times that of the gross national product. The overall price index of inorganic chemicals, however, has fallen

2.5 percent in the recent past. Thus, expenditures for pollution control may be of greater relative significance than in other industries where prevailing rising prices can more readily absorb increased costs.

The regional growth rates reflect a continuing trend to move production facilities closer to raw materials and markets. The industry, as a whole, is thus tending to concentrate in the Midwest and Southwest.

Inorganic chemical plants vary greatly in size, level of technology, product mix, and age. The report presents in considerable detail the description of the various production processes, the waste treatment methods practiced, and the possible impact that changes in processes might have on the volume and character of the wastes produced. A typical or average plant exists, however, only in the statistical sense. The total costs given in this report are for the construction and operation of waste treatment facilities for the industry as a whole and cannot be used to determine costs for individual plants. The costs given are for the waste treatment facilities only. The costs entailed in process changes, restriction of plant operations, sewer segregation, particularly in older plants, are not included. Treatment system construction and operating costs for a particular plant can only be estimated by detailed engineering studies.

Projections based upon the chemical industry data in the 1963 Census of Manufactures, the 1967 Manufacturing Chemists Association survey, the 1968 FWPCA study of the organic chemicals industry, and the costs of treatment for the two levels of 27% and 100% removal of contaminants show the following projected operating costs and cumulative capital investment for wastewater treatment.

PROJECTED CUMULATIVE INORGANIC CHEMICAL INDUSTRY CAPITAL COSTS FOR WASTE TREATMENT, 1969-74

%	Costs in Millions of Current Dollars 1/					
Removal	1969	1970	1971	1972	1973	1974
27	299.3	325.4	359.9	400.1	445.4	494.7
100	1808.4	1964.0	2173.2	2416.3	2689.0	2970.0

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PROJECTED INORGANIC CHEMICAL INDUSTRY ANNUAL OPERATING COSTS FOR WASTE TREATMENT, 1969-74

% Removal	Costs in Millions of Current Dollars [1/]					
	1969	1970	1971	1972	1973	1974
27	82.0	89.1	98.6	109.6	122.0	135.5
100	157.5	171.0	189.2	210.5	234.2	260.2

[1/] Based on an average 3.6% annual increase in the price level

Contaminated wastewater from the inorganic chemical industry comes primarily from electrolysis and crystallization brines, washings from filter cakes, spent acid and alkalies, and washings from raw materials. These wastewaters are generally characterized by dissolved solids and suspended solids. In addition to contaminated waste streams, process cooling discharges occur, accounting for 40 to 80% of the total discharge on the average. Treatment practices vary but involve in-plant segregation of contaminated wastes from uncontaminated cooling waters.

Many waste treatment methods are available depending on the degree of treatment required, however, equalization, neutralization, sedimentation and lagooning processes are most widely used. Biological treatment is not applicable since the contaminants are primarily dissolved or suspended inorganic materials. Plants with small discharges tend to employ only equalization and neutralization with total discharge to municipal sewer systems for joint treatment. It is estimated that between 10 and 20% of the process wastewater discharge from the industry is to municipal systems (4.2% of the total discharge). No significant percentage changes in this regard are expected through 1974. The inorganic chemical industry has generally found that in-plant, separate treatment has economic advantages, particularly when significant quantities of wastewater are involved.

Data from 59 inorganic chemical plants were obtained and formatted according to the Industrial Waste Treatment Practices Data Form, which was developed for the study "The Cost of Clean Water and Its Economic Impact, Volume IV," United States Department of the Interior, January,

1969. The data obtained are given in some detail in the report in terms of bar graphs and various calculated parameters relating wastewater volumes, plant production, and costs.

Key parameters of interest regarding waste treatment costs are the following:

Average capital cost	$223/1000 gpd
Average operating cost/yr.	$58.49/1000 gpd
Average wastewater flow	16.73 gpd/annual ton of production
Average capital cost	$3.74/annual ton of production
Average operating cost	$0.98 per year/annual ton of production

An examination of the survey data showed that the reported bases of waste treatment decisions were generally least cost, or minimum compliance with pollution control regulations.

The costs of unit wastewater treatment methods were developed and are presented in the report as a series of mathematical models and cost function graphs. These data were used to calculate capital costs of waste treatment facilities versus two levels of pollutant removal for a series of typical plants. Treatment Level I was chosen to represent the average treatment employed in the industry as a whole and is judged to be equivalent to 27% removal of suspended and dissolved solids. Treatment Level II represents complete removal of contaminants. Only two levels were selected because the industrial wastes are principally inorganic solids that respond only to physical treatment processes. Because there are no intervening technologies, intermediate levels of efficiency are not distinguishable. The two levels then may be viewed as a range bounded on the one side by the current level of efficiency and on the other by universal application of advanced treatment practices. An almost infinite number of intermediate positions are possible for the industry as a whole within the range, but only as the treatment II technology is applied to individual units of the population. Unlike the case of organic waste, there is no series of technological plateaus through which the whole population may progress.

The following table summarizes the capital and operating costs in 1969 dollars for the two levels of treatment chosen:

% Removal Contaminants	Capital Cost $/1000 gpd	Operating Cost ¢/1000 gal
27 (SS and Acidity)	300	26.0
100 (TDS)	2185	51.5

Since the effective and efficient treatment of wastewater rests with the operators of the waste treatment facility, qualitative as well as quantitative manpower requirements have been projected for the inorganic chemical industry. This report concentrates on the requirements for operation and maintenance since, while administrative and technical support is requisite to effective treatment of wastewater, the qualitative nature of these support requirements will undergo less of a change in future years than will the treatment processes and the skills required for operating and maintaining them. Manpower projections have been made through 1974 with respect to both the degree of commitment necessary to achieve specified levels of effluent quality and the number of persons who must be specially trained to insure effective waste treatment. The several projections should be useful primarily for their planning implications, both to the industry and to affected government agencies. The following table summarizes the estimated trained manpower needs through 1974:

ESTIMATED NUMBER OF TRAINED OPERATION AND MAINTENANCE PERSONNEL REQUIRED FOR WASTEWATER TREATMENT BY THE INORGANIC CHEMICAL INDUSTRIES, 1969-1974

	1969	1970	1971	1972	1973	1974
Large Plants Treatment Level I 27% Removal	1819	1826	1845	1867	1886	1910
Large Plants Treatment Level II 100% Removal	2617	2628	2656	2850	2886	2922
Small Plants Treatment Level I Discharge to Sewers	8906	8968	9052	9150	9255	9365

It must be noted in connection with the above numbers that they are based upon 100% of the indicated size plant utilizing the treatment level shown. There is no estimate of the fraction of large plants utilizing either treatment level except for 1969 where other considerations indicate that on the average all large plants employ Treatment Level I.

CHAPTER II

INTRODUCTION

This study was performed pursuant to Contract No. 14-12-592 with the Federal Water Pollution Control Administration, United States Department of the Interior, and is part of the annual National Requirements and Cost Estimate Study required for presentation to Congress by the Federal Water Pollution Control Act.

The primary objective of this study was to acquire data and develop cost estimates on the waste treatment practices of selected industrial categories within the inorganic chemicals industry over the 1970 to 1974 period, and to develop manpower planning criteria for each of the waste treatment practices identified. A secondary objective of the study was to further test and refine as necessary the generalized methodology for establishing and projecting industry costs which was developed in the course of work under FWPCA Contract No. 14-12-435 "Projected Wastewater Treatment Costs in the Organic Chemicals Industry." This report was transmitted to the Congress in January, 1969 as The Cost of Clean Water, Volume IV.

The information contained in this report is not intended to reflect the cost or waste load situations for any particular plant. A generalized framework for analyzing waste treatment practices has been provided instead. The data and conclusions should be useful to industry and to government in their efforts to find and implement the most efficient ways to reduce pollution of the nation's water bodies.

The study utilized on subcontract the services of Resource Engineering Associates, Inc., Stamford, Conn., Datagraphics, Inc, Allison Park, Pa., and Gurnham, Bramer, and Associates, Inc., McMurray, Pa. Assistance from the Manufacturing Chemists Association in supplying data, comments, and suggestions is gratefully acknowledged.

CHAPTER III

THE INORGANIC CHEMICAL INDUSTRY

The inorganic chemical industry is not easily definable in terms of the Standard Industrial Classification (SIC) numbers. However, for the purpose of this study, it was necessary to define the industry as follows:

2812 - Alkalies and chlorine
2813 - Industrial gases (except for organic gases)
2816 - Inorganic pigments
2819 - Industrial inorganic chemicals, n.e.c.
2851 - Paints and allied products
2871 - Fertilizers (not including ammonia and urea)
2879 - Inorganic insecticides and herbicides
2892 - Explosives

The most important of the groups in terms of product value may be noted as 2819, 2812, and 2871. However, it is not sufficient to ignore such groups as 2813 which includes the important production of nitrogen and oxygen, 2851 which includes the vital surface coatings industry, or 2816 which involves inorganic pigments such as titanium oxide. The surface coatings industry is typical of the relationship which exists between segments of the inorganic industry and the organic chemical industry. The solvents and film formers which are utilized within the inorganic chemical industry for the production of surface coatings are important products of the organic chemical industry while inorganic pigments, primarily oxides and salts of titanium, iron and other metals are products which fall into the inorganic industry category. We have defined the total product as being part of the inorganic industry. However, it is obvious that the complex relationships which exist between various products and industries (necessary to the smooth functioning of our technological state) make it extremely difficult, if not impossible, to arbitrarily associate certain products with one SIC category. Product profiles are given in Appendix C, along with typical product process flow sheets.

The overall output of industrial inorganic chemicals, since they are utilized in a wide range of industries and for a wide variety of purposes usually well removed from the final consumer, depends upon the level of total economic activity rather than economic activity in any specific segment of the economy.

Changes in consumer preferences or redistribution of income and spending, such as changes in tax levels or defense spending, may affect product mixes, but do not significantly affect total industry output. In general, price competition and product substitution are not as significant in the inorganic chemical industry as in the organic chemical sector. However, changes although slow to come tend to be quite profound.

Supplies of raw materials frequently vary and, in the case of certain materials, the industry may face serious shortages until new raw material sources (usually ores or brines) are developed. The widely fluctuating price of sulfur over the past ten years is a classic case resulting from supply fluctuations which can be matched by mercury, potash and silver, among others. Since new sources of minerals are found infrequently and usually involve relatively large expenditures to develop, wide fluctuations in the gap between demand and readily available supply are quite common in the inorganic chemical industry.

Industrial chemical industries are generally capital intensive operations (with a few exceptions such as the paint manufacturing industry), and are characterized by high productivity ($75,000 annual output per production worker), high wages, a low labor turnover, and a continuing demand for skilled labor. Most of the plants operate continuous and must operate at 75 to 85 percent of capacity to maintain adequate levels of efficiency and profitability. Smaller plants generally operate batch processes and, hence, tend to produce low volume, high cost, specialized chemicals. Financial ratios for the industrial chemical industry are shown in Table I.

TABLE I

FINANCIAL RATIOS FOR THE INDUSTRIAL CHEMICAL INDUSTRY

Ratio	1964	1965	1966	1967	1968 [1/]
Profits after taxes/sales (%)	7.9	7.9	7.8	6.5	6.6
Profits after taxes/net worth (%)	14.3	14.7	14.7	10.7	5.7
Capital expenditure/gross plant (%)	7.3	8.6	8.7	5.5	
Depreciation/gross plant (%)	5.8	5.8	5.8	7.0	
Depreciation/sales (%)	4.4	4.4	4.4	4.4	
Depreciation/total assets (%)	1.1	1.1	1.1	1.1	

[1/] First half

SOURCE: U.S. Industrial Outlook, 1969, U.S. Department of Commerce

Profits after taxes as a percentage of sales in the inorganic chemical industry ranged from 6.5 in 1967 to 7.9 in 1964-65. By comparison, comparable profits for all manufacturing industries were 5.0 in 1967 and 5.4 in 1968. It is important to note that while the inorganic segment attracts less attention than the organic sector, satisfactory profits are generally associated with investment in this segment.

The estimated value of inorganic chemical shipments for 1968 and 1969 are shown in II.

TABLE II

VALUE OF ESTIMATED INORGANIC CHEMICAL SHIPMENTS
(1968-9) ($ million)

SIC	1968	1969
2812	891	955
2813	630	665
2816	658	696
2819	4386	4510
2851	3255	3445
2871-72	1815	1815
2879	780	830
2892	501	517

SOURCE: U.S. Industrial Outlook, 1969, U.S. Department of Commerce

Further comparisons within the inorganic chemical industry show that the price index for the chemical industry in mid-1969 was 96.7 on the basis of 1957-59 = 100. In 1968, the level was 98.8. The paint industry price index was 114.4 in 1968 and 118.7 in 1969. The fertilizer industry price level was 102.3 in 1968 and 88.8 in 1969. Several factors distinguish the inorganic chemical industry and its relationship to waste management. Among these are the following:

1. While certain segments of the industry are growing rapidly, the more common situation is for a growth rate at 1.5 to 2 times that of the gross national product and several of the major chemicals have growth curves which might be substituted for a

historical projection of industrial growth in general. This strong growth will affect the need for pollution control facilities.

2. Capital investment is generally considerable and, because of the nature of inorganic chemistry and its long history of relatively unchanging practice, rapid technological obsolescence does not occur. Consequently, new capacity is not quickly built. This industry moves more slowly to increase plant capacity than the organic chemical industry for example. Accordingly, the inorganic chemical industry with its relatively aged plant in place faces relatively high expenditures for added pollution control facilities.

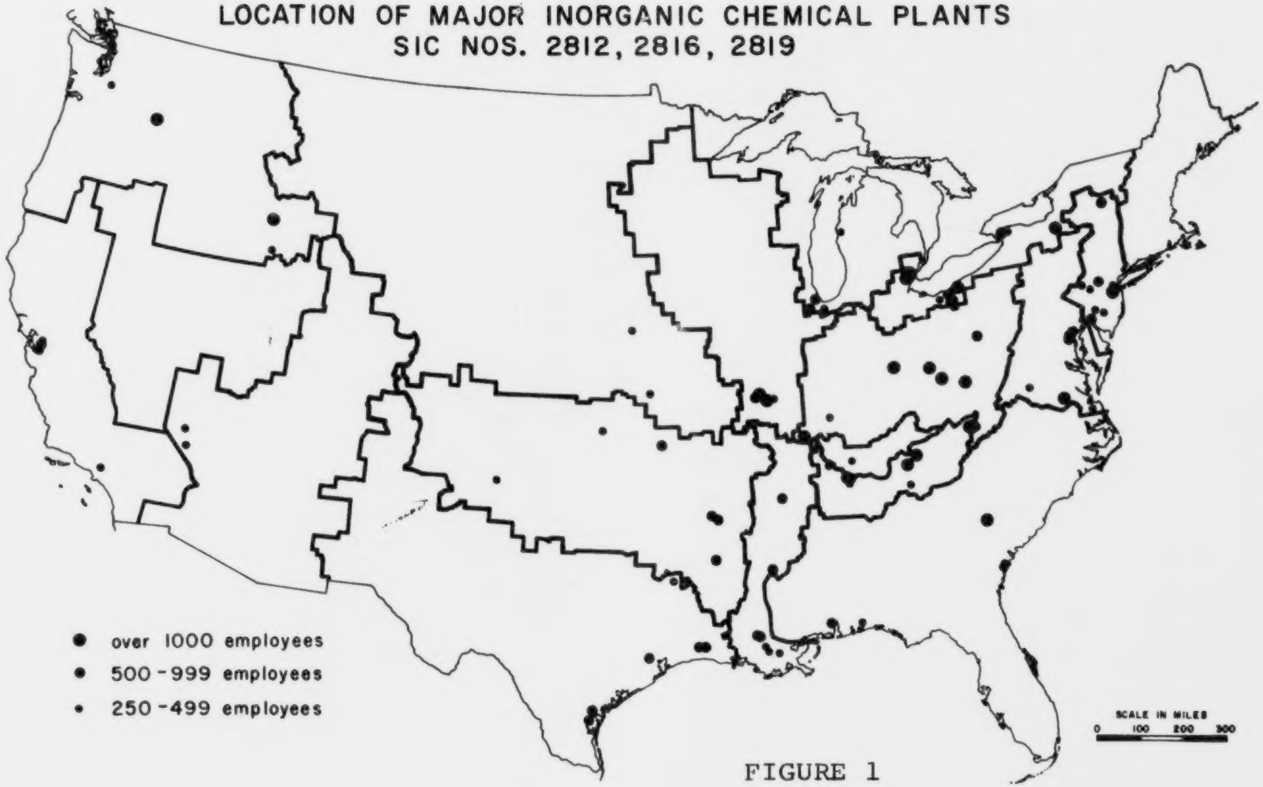
3. The overall price index of chemicals, in contrast with the general experience of American industry, has fallen two to five percent in the recent past. Thus, expenditures for pollution control may be of greater relative significance than in other industries where prevailing rising prices can more readily absorb increased costs.

4. Inorganic chemical plants tend to be located to take advantage of such business factors as the availability of raw materials, low cost power, or markets. Considerations relating pollution control and plant location have been of minor importance in the past.

5. Many facilities are old and completely depreciated. Accordingly, there is little incentive to build pollution control facilities to handle wastes from an obsolete operation. Because of the nature of the industry, obsolete units remain sufficiently profitable to continue in use.

6. Characteristically, inorganic chemicals are handled in only two or three steps from raw material (brine or ore, usually) to product for use by industry elsewhere. While the inorganic chemical industry includes a large number of products and processes with the possibility of many different products at a particular production site, there are a limited number of products which comprise the bulk of the

value of this industry's production; these are discussed in detail in Appendix C to this report along with the wastes generated by their production. The location of this portion of the industry's production is shown on Map A.



LOCATION OF MAJOR INORGANIC CHEMICAL PLANTS
SIC NOS. 2812, 2816, 2819

● over 1000 employees
● 500 - 999 employees
• 250 - 499 employees
SCALE IN MILES
0 100 200 300

FIGURE 1

This map represents a compilation, in content and configuration, of the location of major inorganic chemical plants classified by SIC 2812, 2816, and 2819. The source of this information was the book by Barry R. Lawson, *Atlas of Industrial Water Use – A Report to the Water Resources Council,* Cornell University Water Resources Center, Ithaca, New York, Publication No. 18, September, 1967, pp. 21, 25 & 29.

CHAPTER IV

PROJECTED INDUSTRY GROWTH

During the next decade, the inorganic chemical industry will be characterized by new technology and many new products. Many large volume chemicals are likely to face changing markets as synthetic materials replace natural products and one inorganic chemical is replaced by another. Some of the processes that will bring changes in inorganic chemicals utilization include hydrocracking in gasoline refining, oxygen use in steelmaking and in blast furnaces, holopulping to eliminate chemical markets in papermaking, the use of hydrochloric acid in steel pickling, the production of phosphoric acid from hydrochloric or nitric acid, the recovery of chlorine from by-product hydrochloric acid, the recovery of sulfur compounds from power plant flue gases, the use of oxygen in sparging rivers, streams, and sewers as a pollution abatement measure.

Inorganic chemicals represent a rapidly growing sector of the chemical industry. In the 1963-69 period, the production of inorganic chemicals as measured by the U.S. Department of Commerce production index rose about 12% per year compounded, compared to a 7% rate for the previous five years. Prices in the industry, however, have risen only 5.3% per year during 1963-68 due to both competitive pressures and to improved production efficiencies.

Projected growth in the industry, for the purposes of the present study, are best expressed in terms of the volume of production based upon the tonnages of chemicals produced. Growth estimates have been obtained from a study by Resource Engineering Associates, Stamford, Conn., utilizing an analysis which incorporates estimates of overall employment, rate of growth of the economy, and other economic parameters, as well as specific characteristics of the industry and marketability prospects for its products. These data are considered to be the most reliable available and are tabulated in Table I.

TABLE I

PRODUCTION OF INORGANIC CHEMICALS
(millions of tons unless otherwise noted)

SIC	1968	1969	1970	1971	1972	1973	1974
2812	24	25	26	28	30	32	34
2813 1/	365	420	495	595	715	850	1000
2816	1.20	1.25	1.29	1.37	1.44	1.51	1.59
2819	70	72	74	77	80	84	88
2851 3/	843	899	944	1000	1060	1124	1191
2871	41.50	41.80	42.25	43.94	46.14	47.99	49.91
2879	0.20	0.20	0.19	0.18	0.18	0.17	0.15
2892 2/	250	264	274	282	293	305	322

1/ High purity oxygen and nitrogen only (billions of cu. ft.)
2/ Millions of dollars
3/ Millions of gallons

The above data are applicable to the inorganic chemical industry as a whole, but rates of growth vary in the various segments of the industry and from one geographical region to another. Expected rates of growth over the next decade according to industry segment and according to geographical region are given in Tables II and III.

TABLE II

INDUSTRY SEGMENTAL GROWTH RATES THROUGH 1979

SIC No.	Growth Rate (%/year)
2812	6
2813	18
2816	5
2819	4
2851	6
2871	4
2879	1
2892	4

SOURCE: REA Projections

The above growth rates are based upon volumes of production and assume a real growth in the Gross National Product of 3.5% per year.

TABLE III

INDUSTRY GROWTH RATES GEOGRAPHICALLY THROUGH 1975

Region	Growth Rate (%/year)
Northeast and Middle Atlantic	4
Southeast	6
Gulf Coast	5
North Central	10
Mid South	10
Mountain States	4
Pacific Coast	5

SOURCE: REA Projections

The regional growth rates reflect the continuing trend to move production facilities closer to raw materials and markets. The industry will thus tend to concentrate more heavily in the Midwest and Southeast.

CHAPTER V

WASTEWATER CHARACTERISTICS

Wastewater from inorganic chemical processing consists both of contaminated and relatively clean effluent streams. In general, the contaminated wastewaters are those taken from processes while the cleaner wastewaters are those used for indirect heat exchange, general washing, etc.

Contaminated Wastewaters

The major sources of contaminated wastewaters are as follows:

1. Brines arising from electrolysis and crystallization
2. Filter cake washings
3. Waste acid and alkaline streams
4. Washing streams containing substantial amounts of suspended particulate matter

These waters are generally characterized by dissolved solids and suspended solids. Typical sources are discussed in connection with the various processes described in detail in Appendix C of this report.

Clean Wastewaters

Clean waters, which are basically uncontaminated and can be discharged untreated, are not included in the total flows given in wastewater totals. Cooling water and steam condensates are the primary sources of such water, and a typical breakdown is given in Table I.

Also included is an indication of potential pollutants and associated sources and concentrations. Because these clean wastewaters are relatively uncontaminated and exert little pollutional effect (except thermal) on the environment, care must be exercised to prevent their contamination.

The thermal effects cannot be ignored. Effluent heat loads can adversely affect the surface receiving waters, causing decreased oxygen solubility and greater oxygen utilization. Both of these effects significantly

TABLE I

COMPOSITION OF TYPICAL CLEAN WATER EFFLUENT

Water Sources	% of Total Wastewater	Flow Range (gpm)	Potential Pollutant Sources
Cooling Water (excluding sea water)	40 - 80	100 - 10,000 (500 - 200,000 (gal. water ton product)	Process leaks: Bearings, exchangers etc.
Steam Equipment	10	50 - 1,000	Water treatment Scrubbed from air through tower Make-up water Boiler blowdown Waste condensate

reduce the ability of the receiving water to assimilate waste loads. Through the use of cooling towers, the quantity of high temperature wastewaters discharged has been greatly reduced.

The segregation of clean wastewater flows is widely practiced throughout the inorganic chemical industry, as a result of overall wastewater treatment economics and regulatory requirements. Although there is a limited possibility that wastewater flows can be further reduced by segregating additional clean waters, most major clean waters are currently collected and either recirculated or discharged separately in those inorganic chemical plants with treatment facilities.

Thermal Pollutants

Many process facilities in the inorganic chemical industry generate large amounts of thermal energy which must be removed by the circulation of cooling waters or air. Additional heat is released through the release of hot brines from evaporators, etc. Of particular significance are the gas producing plants because of their need to discharge the thermal energy extracted from air or natural gas during their compression and cooling to subzero temperatures. In many cases, the problems of thermal pollution are reduced through the use of cooling towers. In the latter case, the blowdown from such recirculating systems may contain substantial amounts of chemicals added to the cooling water such as chromates, zinc, phosphates, bactericides, organics, etc., which may constitute a pollution problem.

In the case of many industries, there is concerted effort to produce by-product steam from excess thermal energy. In the manufacture of sulfuric acid, for example, by-product steam is important to process economics. In many other cases, however, waste hot brines and other similar waste flows are held in ponds for cooling prior to discharge into surface waters.

CHAPTER VI

WASTEWATER TREATMENT METHODS

A variety of sequences of wastewater treatment are available for wastes from inorganic chemical manufacture. Their use depends on the nature of the waste and treatment requirements. These sequences are indicated in Figure 1. Three typical cases will be presented. These are:

I. Waste-containing dissolved and suspended solids
II. An excess thermal energy discharge
III. Waste-containing dissolved solids

Treatment Sequence I

In this case, the proposed treatment sequence might be:

Liquid 2-3-4-7-11-15 (Note that 8, 9, and 10 can substitute for 7 and 11)
Solids 15-14-12-19

In this sequence, the waste flow is equalized and oil is removed, clarification is used for suspended solids removal, and the dissolved solids are concentrated and sent to a deep well for disposal. The effluent distillate is then discharged or reused. The suspended solids slurry will be thickened, centrifuged, and disposed of in a lagoon. Alternately, chemical addition could be used for dissolved solids removal if the dissolved ions have a common insoluble salt. Then the dissolved ion problem has been converted to a suspended solids problem and a suspended solids removal and disposal sequence of 4-15-14-12 would be followed. It is also possible to concentrate the dissolved ions by electrodialysis, or by ion exchange instead of distillation and the sequence would be similar to that described above.

The blowdown from the dissolved solids concentration step instead of being disposed in a deep well may be distilled to dryness, solar evaporated, or converted to a saleable product.

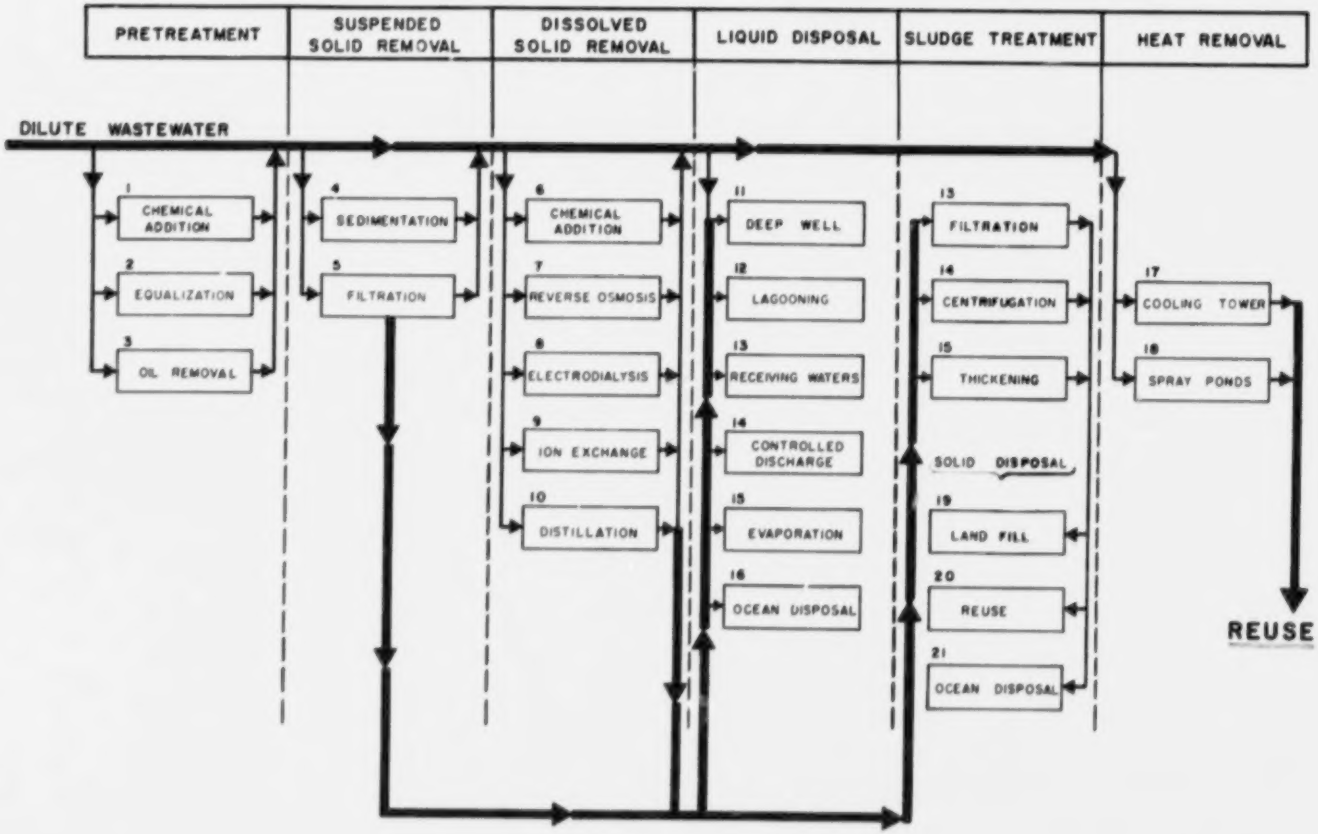

PRETREATMENT
SUSPENDED SOLID REMOVAL
DISSOLVED SOLID REMOVAL
LIQUID DISPOSAL
SLUDGE TREATMENT
HEAT REMOVAL
DILUTE WASTEWATER
1 CHEMICAL ADDITION
2 EQUALIZATION
3 OIL REMOVAL
4 SEDIMENTATION
5 FILTRATION
6 CHEMICAL ADDITION
7 REVERSE OSMOSIS
8 ELECTRODIALYSIS
9 ION EXCHANGE
10 DISTILLATION
11 DEEP WELL
12 LAGOONING
13 RECEIVING WATERS
14 CONTROLLED DISCHARGE
15 EVAPORATION
16 OCEAN DISPOSAL
13 FILTRATION
14 CENTRIFUGATION
15 THICKENING
SOLID DISPOSAL
19 LAND FILL
20 REUSE
21 OCEAN DISPOSAL
17 COOLING TOWER
18 SPRAY PONDS
REUSE

FIGURE 1
WASTEWATER TREATMENT SEQUENCE

Treatment Sequence II

Here the proposed treatment sequence would be:

17-6-4-13

That is, a cooling tower (or a spray pond) would be installed and the cooled effluent discharged or recycled. If recycling is used, then the blowdown from the system may be treated by chemical addition and clarification to remove undesirable components (especially hexavalent chrome and zinc added for corrosion control) prior to discharge. The suspended matter would then go into a suspended solids disposal sequence discussed above.

Treatment Sequence III

With a very light suspended solids load but a heavy dissolved solids load, the sequence (with excess acidity) would be:

2-1-7-11-13

where neutralizing would be prescribed following equalization. This would be followed by reverse osmosis (or distillation, electrodialysis, ion exchange or chemical addition depending upon the circumstances) and discharge. The concentrate would be disposed of in a deep well or evaporated to dryness.

At this point, it is important to note the existence of two significant treatment sequences of general importance. They are:

	Treatment Sequence
a) excessive acidity or alkalinity streams	1
b) many high dissolved solids streams	2-5-11

The above two treatment sequences are commonly used in many circumstances in this industry. These treatment sequences, of course, do not represent all those used by the industry but are considered to be the most prevalent.

Joint Industrial Municipal Treatment

According to the U.S. Department of Commerce's 1963 publication, Water Use in Industry, (the most recent available report), a total of 1.178 trillion gallons of water (excluding SIC 2813 Industrial Gases) were discharged from plants of this industry group. Of this total, some 48 billion gallons, or 4.2%, were discharged to municipal systems. No significant changes with regard to the percent discharged to municipal systems has occurred in the intervening years. However, these studies, which are supported by others, indicate that there is tremendous variation within groups. The study (see Table I) indicates that the SIC groups 2812, 2819, 2871, and 2892 do not make significant use of municipal systems, undoubtedly because of the nature of their discharges (high chlorides, conservative species, low or high pH) and their volume as well as the location of the plants. SIC 2813 and 2851 make extensive use of municipal systems. The data for 2813 were not available, but because of the plant locations and the fact that the waters discharged are primarily cooling waters, it is estimated that 40 percent goes into municipal systems. The data on SIC 2879 are inconclusive and that on 2816 indicate that a significant though not necessarily major percentage of the plants do use municipal facilities.

The data in Table I apply only to plants reporting water use of at least 20 million gallons per year or having more than 100 employees. The distribution of employees and water use is shown in Tables II and III.

More up to date data were not available from the Bureau of Census and probably will not be available until the latter part of 1970. However, the general trend of data is not significantly changed and the conclusions expressed are based on a review of updated trends.

TABLE I

WATER DISCHARGE BY SIC (1)

Inorganic Industry	SIC	Total Discharge (billion gals/yr)	Discharge to Municipal Systems (billion gals/yr)	Percent to Municipal Sewers
Alkalies	2812	509	21	4.2
Gases	2813	Not available		Estimated at 40% 1/
Pigments	2816	100	11	11.0
Chemicals	2819	447	13	2.9
Paints	2851	5	3	60.0
Fertilizers	2871	89	Less than 0.5	0.0
Herbicides	2879	1	Less than 0.5	0.0
Explosives	2892	27	Less than 0.5	0.0

1/ by Research Engineering Associates, Stamford, Conn.

(1) U.S. Census Bureau, Census of Manufactures (1963), Water Use in Manufacturing

TABLE II

EMPLOYMENT DISTRIBUTION (1)

Number of Employees	SIC							
	2812	2813	2816	2819	2851	2871	2879	2892
1-4	1	134	20	168	500	44	105	12
5-9	-	70	14	90	309	20	61	4
10-19	-	106	13	93	325	18	62	5
20-49	1	98	14	111	343	71	71	7
50-99	9	35	11	75	160	73	26	9
100-249	10	12	10	74	114	40	9	18
250-499	4	1	8	33	29	13	5	6
500-999	7	-	4	18	6	1	1	3
1,000-2,499	5	-	2	8	2	1	-	3
2,500 and more	1	-	-	4	-	-	-	1

(1) U.S. Census Bureau, ibid

TABLE III

DISTRIBUTION OF WATER USE (1)

Number of Establishments Reporting Indicated Water Use (mil. gal/yr)	SIC							
	2812	2813	2816	2819	2851	2871	2879	2892
Less than 1	4	197	32	189	981	104	218	28
1-9	2	106	13	98	162	50	23	4
10-19	1	36	4	39	28	24	2	5
20-99	2	33	7	60	38	32	7	4
100+	29	49	20	138	15	31	3	17

(1) U.S. Census Bureau, ibid

The smallest plants tend to discharge effluent to municipal sewers but they also tend to discharge small volumes of water. If we assume that they discharge all of their effluent water to municipal sewers, the figures change as shown below:

SIC	Percent to Municipal Sewers From Table I	Percent to Municipal Sewers Recalculated
2812	4.2	4.2
2816	11.0	11.2
2819	2.9	3.3
2851	60.0	75.0
2871	0.0	1.6
2892	0.0	0.0

Thus, the total discharge on a percentage basis is not significantly changed and would approximate 4.5 percent of the total.

It is significant to note that the total percentage, and that within an SIC group, is not going to increase significantly in the future. Spreading municipal systems and increasing pressure on industry to treat its wastes will be counter-balanced by restrictions on discharges into municipal systems which will be especially true with regard to discharges from the inorganic chemical industry. It is likely that waste streams currently being discharged into municipal systems from this industry's establishments will be reduced because of increasingly stringent sewer restrictions. The main point is that there is not much point in co-treating a highly conservative, dissolved solids waste stream in a facility designed to treat non-conservative, suspended and colloidal solids wastewaters.

Sewer restrictions which may bar or establish limitations on chlorides, total dissolved solids, suspended solids, heavy metals, color, pH, etc., are the principal barriers to the acceptance of wastewaters from this industry into a municipal system. Economics rarely play a role since almost any charge levied by a municipality would be cheaper than known techniques for treating inorganic dissolved solids in most locations where direct discharge to receiving streams is not permitted.

Rates vary from the infrequent zero cost to a rate on a par with residential customers up through above average costs based on surcharges or intentional industrial burdens. Charges may run from $0.10-$1.00/1000 gallons with a level of $0.30-$0.40/1000 gallons at the 30-50 mgd treatment level believed to be average.

The chemical industry has generally found that in-plant, separate treatment for neutralization and suspended solids removal has economic advantages, particularly when significant quantities of contaminated wastewaters are involved. No significant percentage increase in the amount of wastewaters treated in municipal systems is expected in the near future. If complete, water renovation of municipal wastewater becomes common, however, then joint treatment for this industry's wastewater might become more common and desirable.

CHAPTER VII

INDUSTRIAL WASTE TREATMENT PRACTICES DATA FORM

An important secondary objective of this study has been to further develop and refine as necessary generalized methodology for establishing and projecting industry costs. The Industrial Waste Treatment Practices Data Form was developed as a part of the study entitled "Projected Wastewater Costs in the Organic Chemicals Industry" under Federal Water Pollution Control Administration Contract No. 14-12-435 and published as a part of "The Cost of Clean Water and Its Economic Impact - Volume IV," United States Department of the Interior, January, 1969.

This form has been utilized in the acquisition of data for the present study and has been expanded to include data on manpower requirements in waste treatment practices. Although no major changes were made in the original form, an additional card (Card 10) has been added to incorporate manpower data. Those changes that were made were generally either to enlarge or reduce code fields as indicated by the volume of data.

The Industrial Waste Treatment Practices Data Form now consists of ten or more data sheets corresponding to ten types of punched cards. Data sheets 1, 2, and 5 require only one punched card, whereas sheets 3, 4, 6, 7, 8, 9, and 10 may each require several cards in order to satisfy large volumes of data.

In the course of completing both the present and previous studies, an operating set of instructions along with a dictionary for coded materials was prepared and expanded. Since all data must be prepared in a uniform manner to facilitate either manual or machine tabulation, the operating instructions shall interpret all questions for the data collector, while the dictionary will provide alternative answers along with the codes. If an entry cannot be adequately described by a dictionary code, the code fields are to be left blank; such codes will be assigned by the Data Center.

The ten data sheets comprising the Industry Waste Treatment Practices Data Form along with the operating instructions and dictionary are shown in Appendix A.

The data forms have now been tested on 111 plants in the chemical industry which vary widely along the selected parameters. The utility in tabulating data for either a single plant or general industry has proved successful and acceptable.

CHAPTER VIII

PLANT SURVEY DATA

The Industrial Waste Treatment Practices Data Form was used to tabulate data from 59 inorganic chemical plants. The basic data obtained are tabulated in Appendix B and are portrayed in the bar graphs of Figures 1 to 9.

From those plants for which adequate information was available, the following average statistics were calculated:

Average production = 280,734 tons per year
Water use per plant = 27,034,619 gpd
Wastewater discharge per plant = 4.697 mgd
Average treatment efficiency = 85%
Average capital costs of treatment facilities = $1,048,578
Average operating costs of treatment facilities = $274,730 per year

Generalizing the above data:

Average capital cost = $223/1000 gpd
Average operating cost = $58.49 per year/1000 gpd
Average wastewater flow = 16.73 gpd/annual ton of production
Average capital cost = $3.74/annual ton of production
Average operating cost = $0.98 per year/annual ton of production

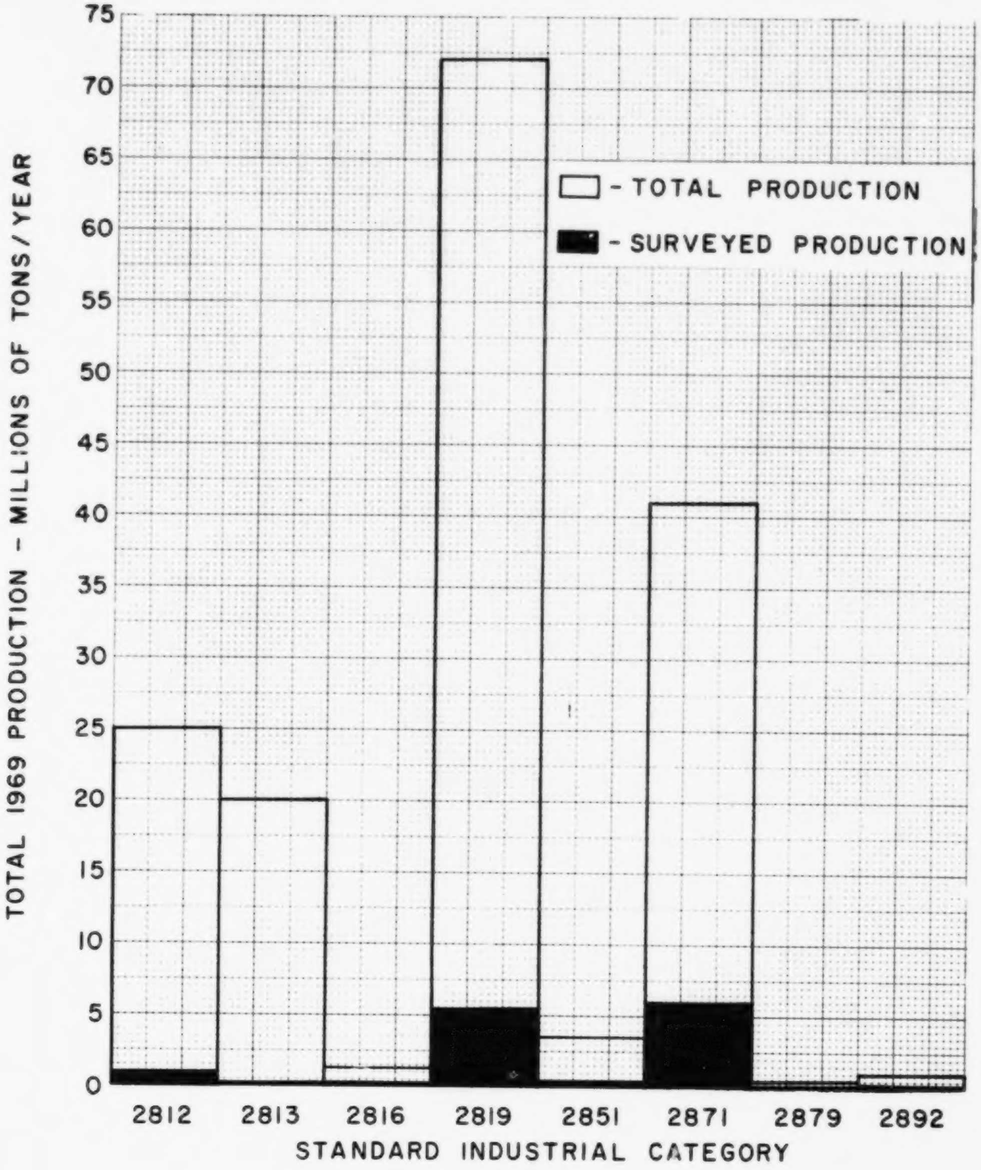
The generally fragmentary nature of the survey data is indicative of the status of wastewater treatment in this segment of the chemical industry. Wastewater treatment practices tend to be those which reduce gross pollutants such as acidity, oil, and suspended solids. The refractory nature of the wastes from most of the industry's processes would require more advanced treatment technologies than have generally been applied.

The production, capital costs, and operating costs data reported per plant are judged to be reliable. Such data are easily obtained from plant records. The data reported on wastewater flows, however, are not sufficiently reliable to be used for projection calculations; these data are in error in that contaminated wastewater flows are not accurately differentiated from cooling water effluents.

Even though an extensive correlation study was made, no statistically significant relationships were found among the various cost-related parameters. The relationship indicated in Figure 10 showing operating costs of treatment facilities per ton of annual production as a function of capital costs of facilities per ton of annual production is the most useful found; it can be used to indicate at least order-of-magnitude variations.

Among the plants in the survey sample, production capacities were generally low while wastewater volumes reported tended to be high. Most of the plants employed more than 100 persons and were less than 10 years old. The plants were widespread geographically and, accordingly, may be considered to be representative in this regard. The bases of treatment decisions for these plants were generally least cost or minimum compliance with regulations. A few decisions were made on the basis of a projected economic return and only one plant decision was based on ultimate treatment.

FIGURE 1



75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
TOTAL 1969 PRODUCTION - MILLIONS OF TONS/YEAR
☐ - TOTAL PRODUCTION
■ - SURVEYED PRODUCTION
2812
2813
2816
2819
2851
2871
2879
2892
STANDARD INDUSTRIAL CATEGORY

FIGURE 2

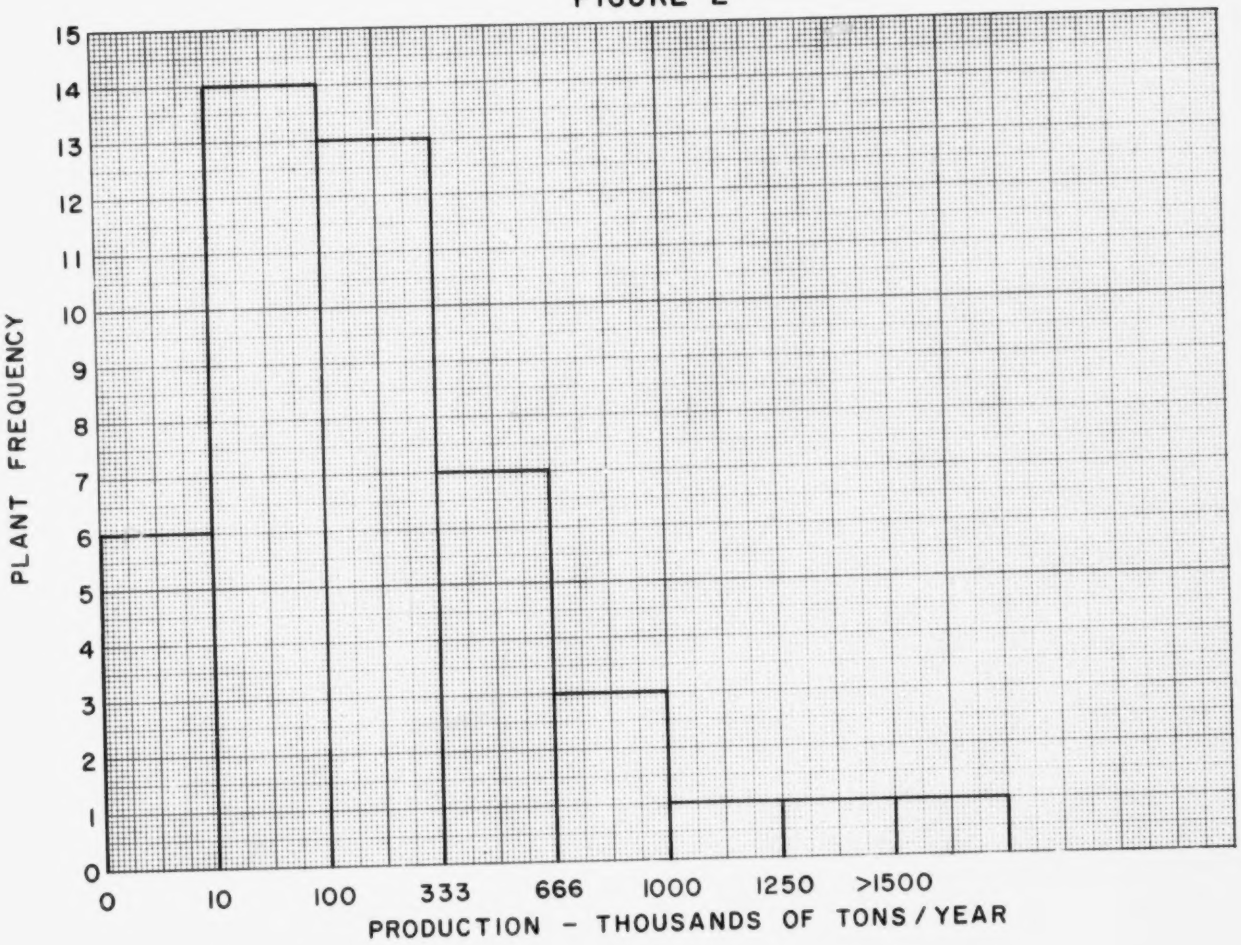

PLANT FREQUENCY
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
10
100
333
666
1000
1250
>1500
PRODUCTION - THOUSANDS OF TONS / YEAR

FIGURE 3

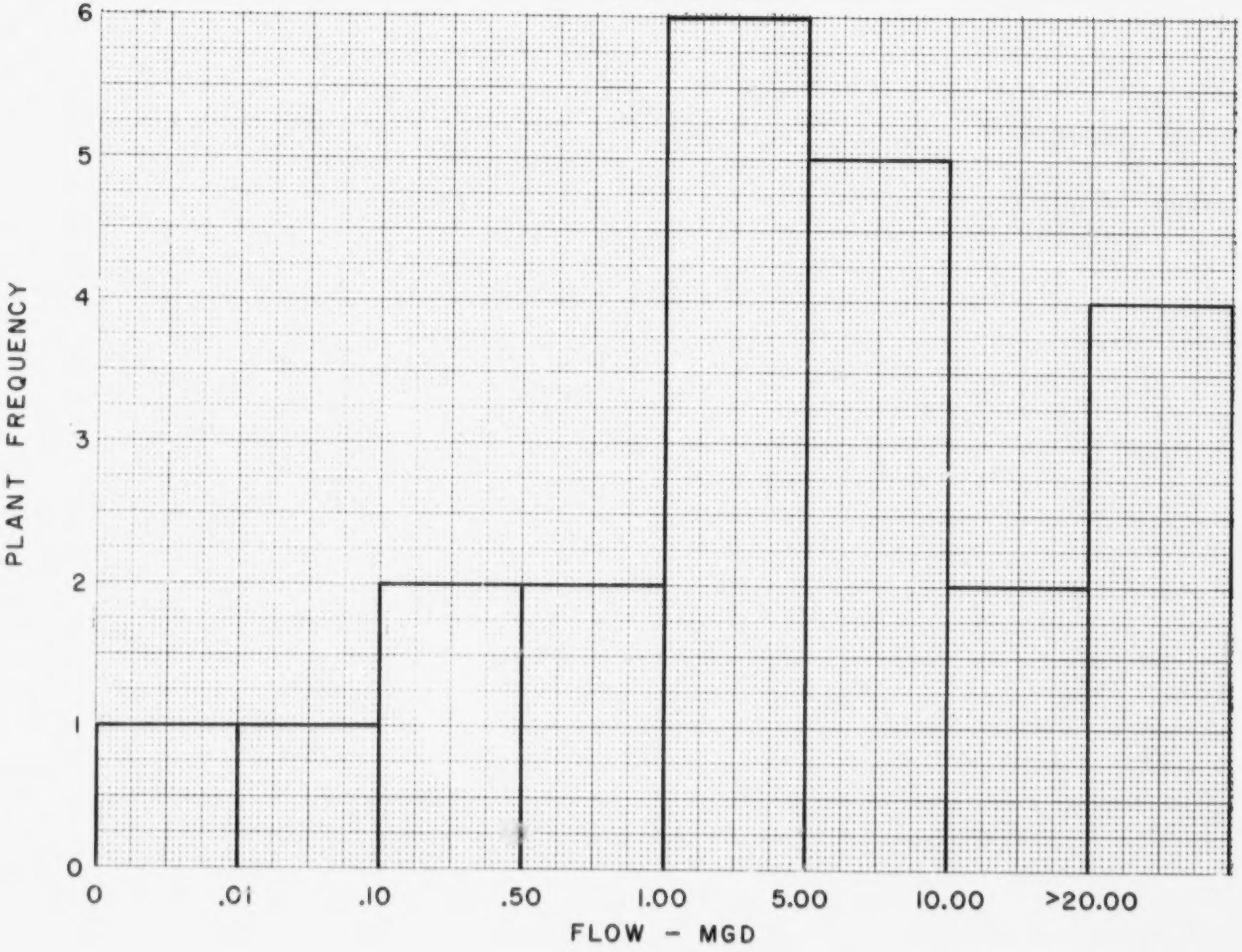
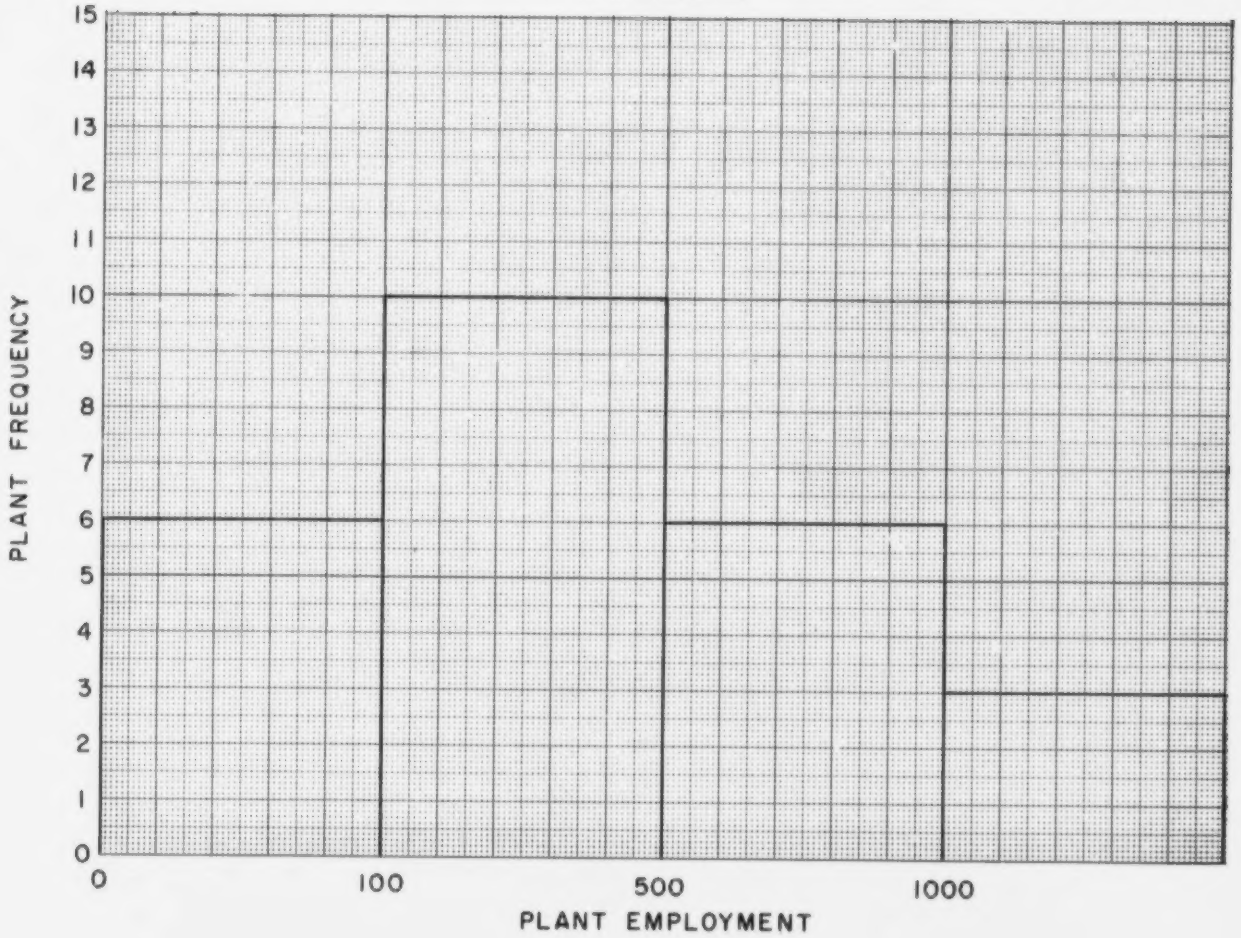


FIGURE 4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8
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6
5
4
3
2
1
0
PLANT FREQUENCY
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100
500
1000
PLANT EMPLOYMENT

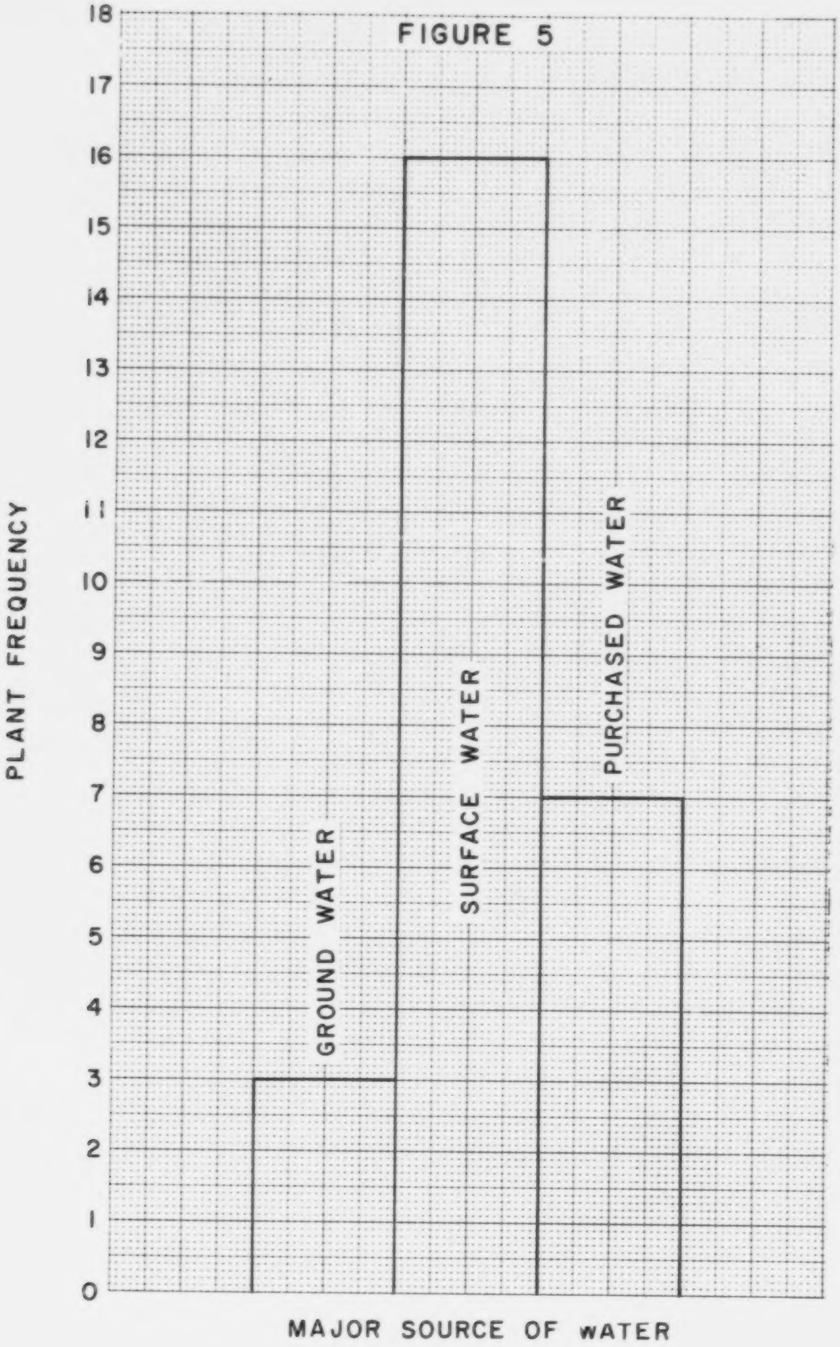


FIGURE 5

PLANT FREQUENCY
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
GROUND WATER
SURFACE WATER
PURCHASED WATER
MAJOR SOURCE OF WATER

FIGURE 6

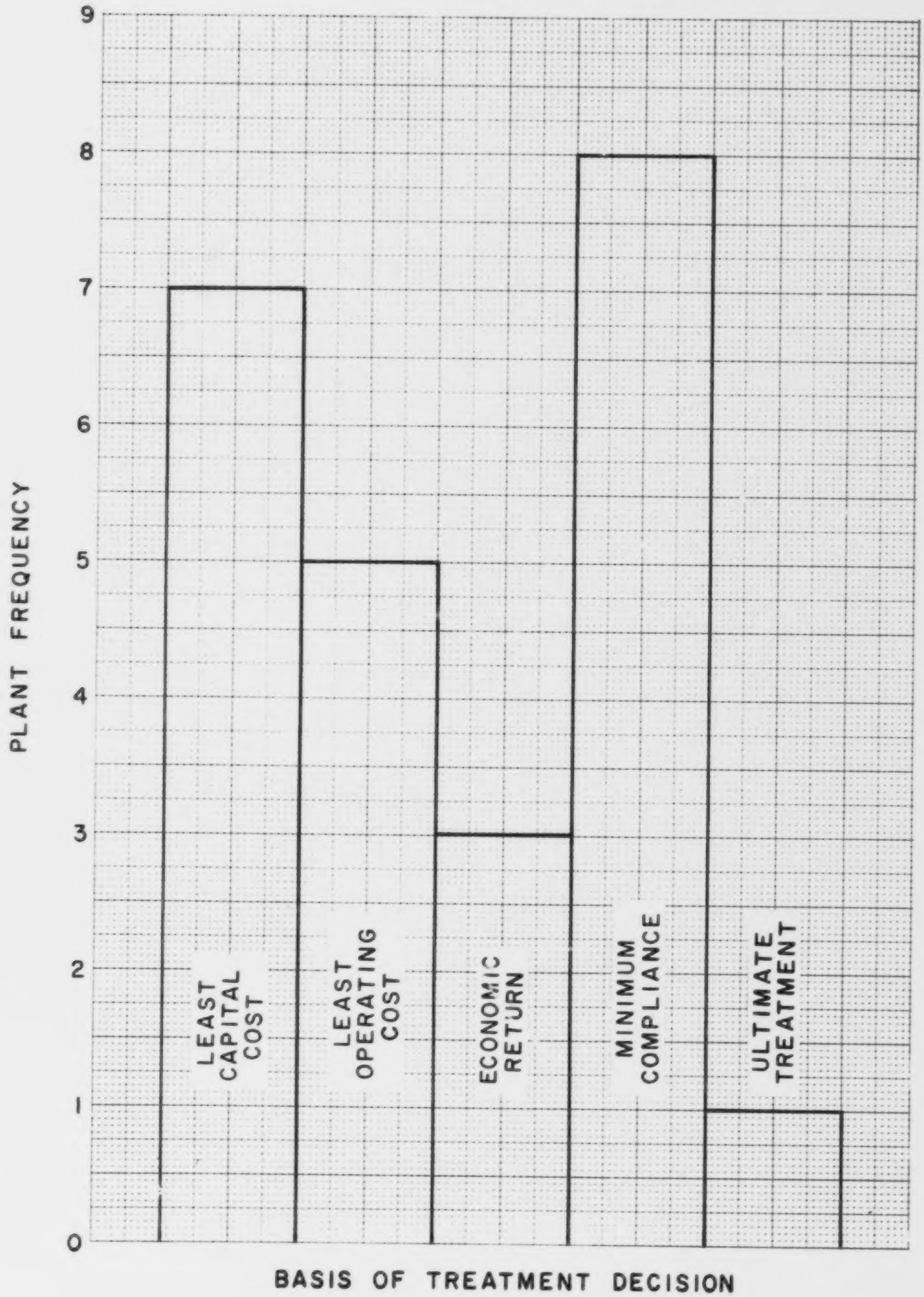

9
8
7
6
5
4
3
2
1
0
PLANT FREQUENCY
LEAST CAPITAL COST
LEAST OPERATING COST
ECONOMIC RETURN
MINIMUM COMPLIANCE
ULTIMATE TREATMENT
BASIS OF TREATMENT DECISION

FIGURE 7

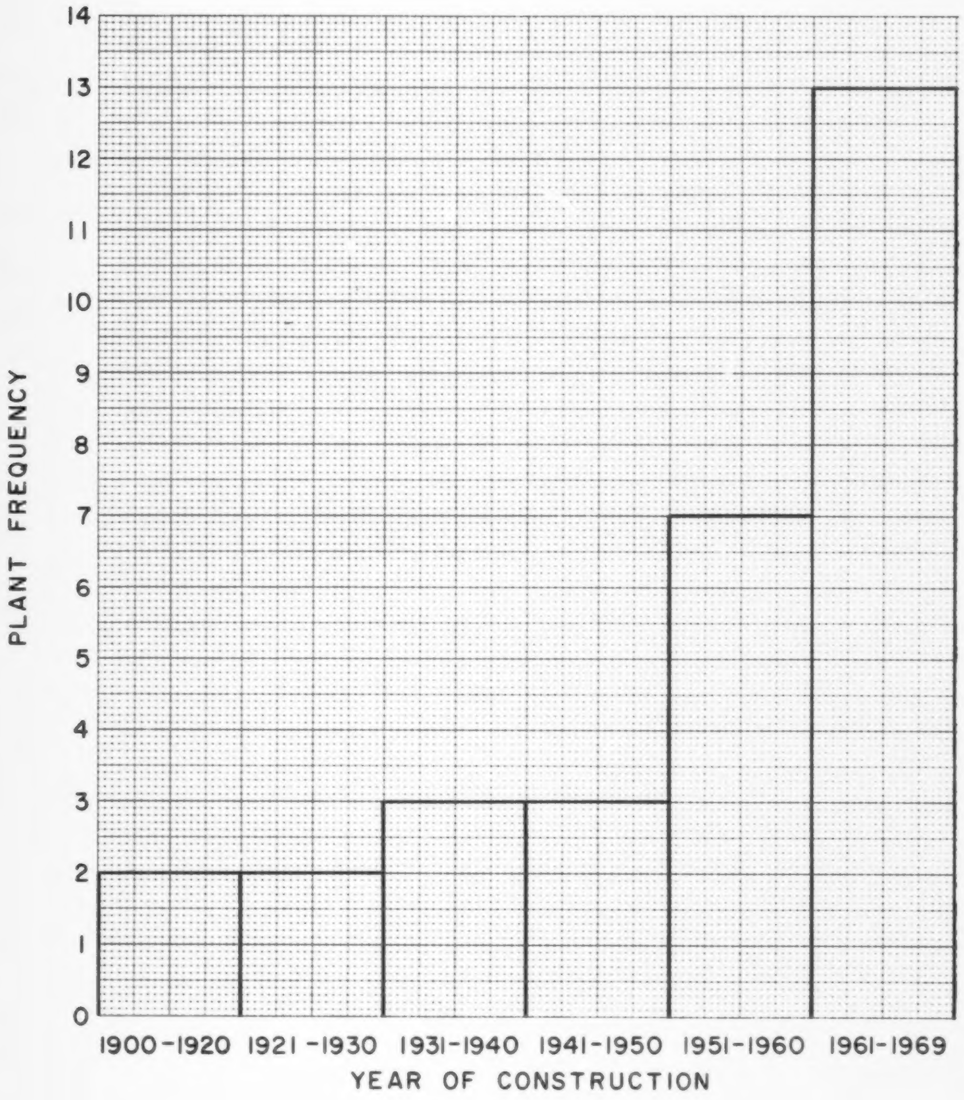
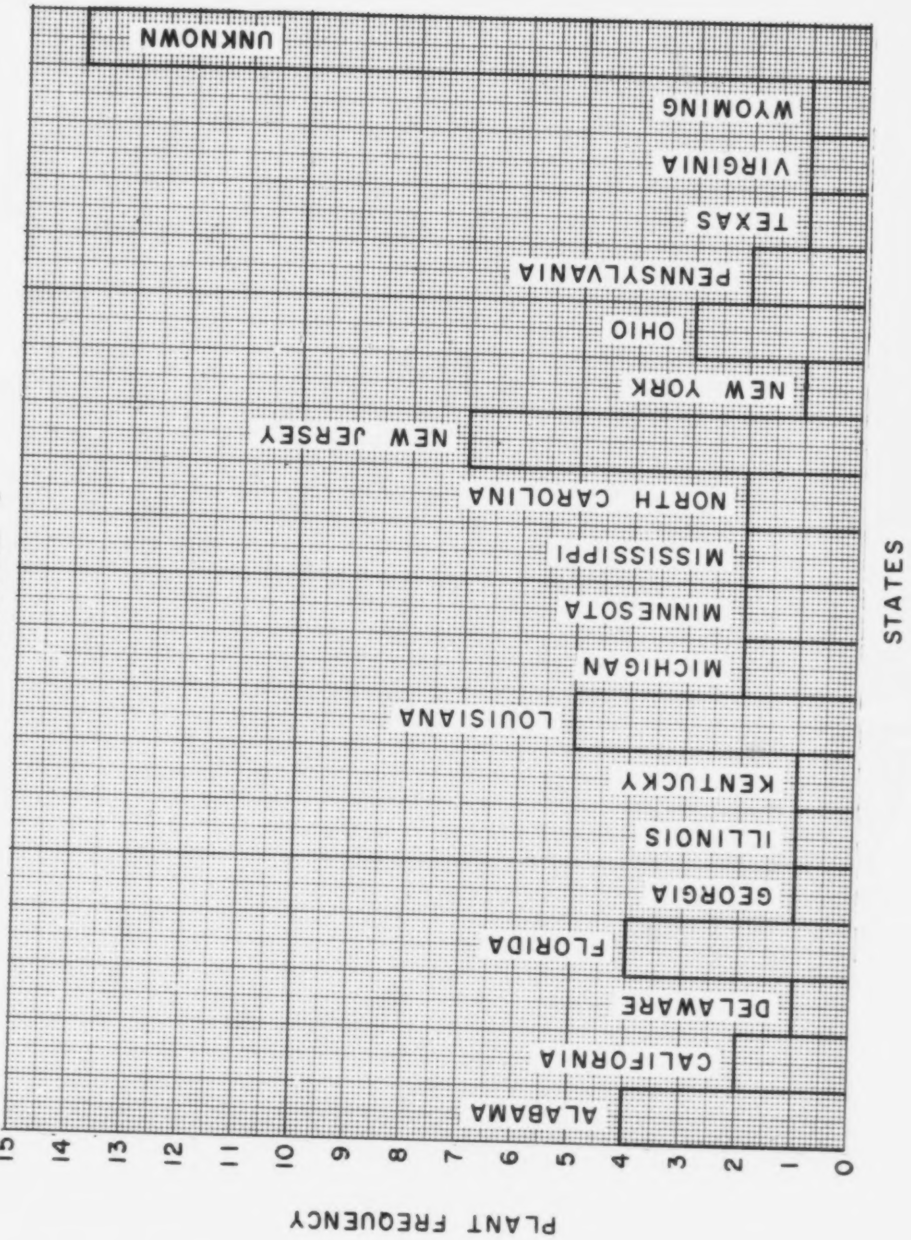

14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
PLANT FREQUENCY
1900-1920
1921-1930
1931-1940
1941-1950
1951-1960
1961-1969
YEAR OF CONSTRUCTION

FIGURE 8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VIRGINIA
TEXAS
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OHIO
NEW YORK
NEW JERSEY
NORTH CAROLINA
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MICHIGAN
LOUISIANA
KENTUCKY
ILLINOIS
GEORGIA
FLORIDA
DELAWARE
CALIFORNIA
ALABAMA
15
14
13
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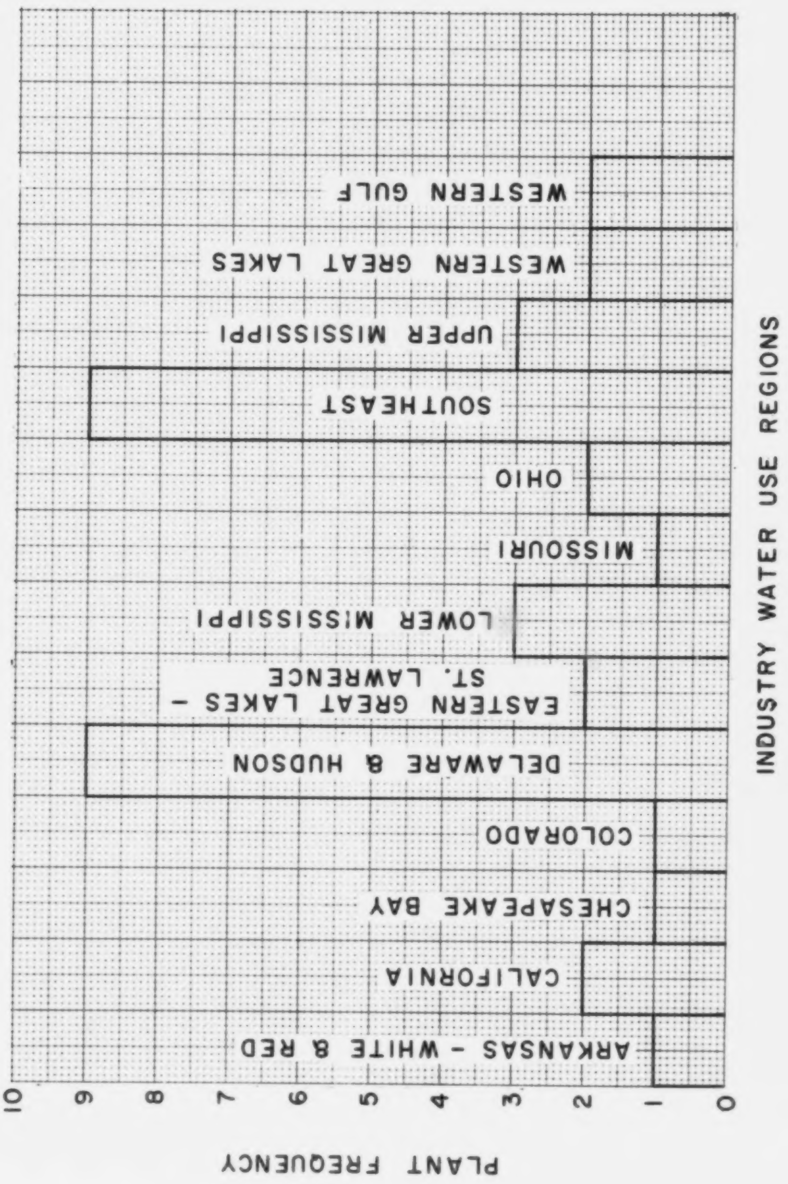
0
PLANT FREQUENCY
STATES

FIGURE 9


INDUSTRY WATER USE REGIONS
PLANT FREQUENCY
0
1
2
3
4
5
6
7
8
9
10
ARKANSAS - WHITE & RED
CALIFORNIA
CHESAPEAKE BAY
COLORADO
DELAWARE & HUDSON
EASTERN GREAT LAKES - ST. LAWRENCE
LOWER MISSISSIPPI
MISSOURI
OHIO
SOUTHEAST
UPPER MISSISSIPPI
WESTERN GREAT LAKES
WESTERN GULF

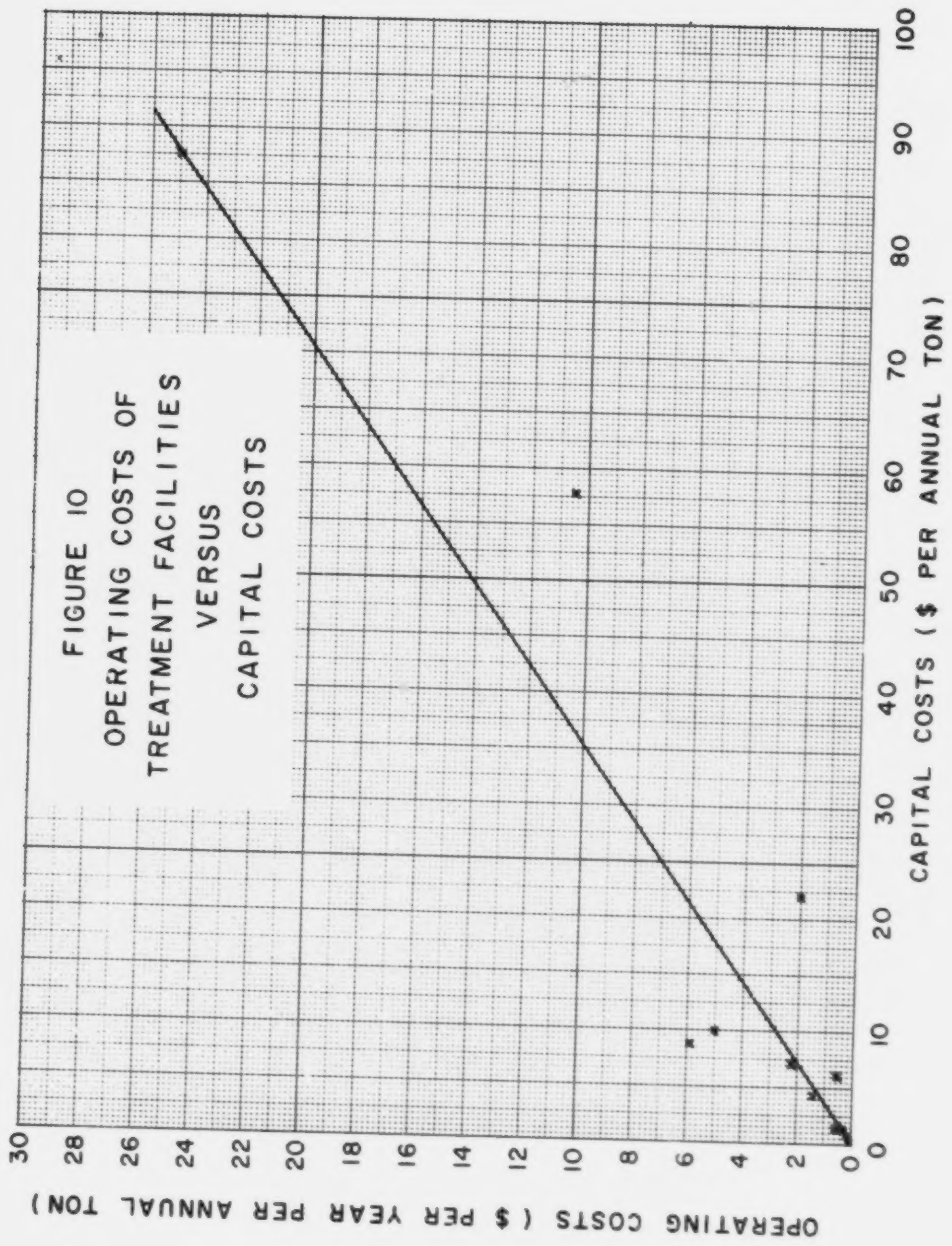


FIGURE 10
OPERATING COSTS OF
TREATMENT FACILITIES
VERSUS
CAPITAL COSTS

CHAPTER IX

COSTS OF UNIT WASTEWATER TREATMENT METHODS

Introduction

The composition of wastes from the inorganic chemical industry are very unpredictable, but the types of pollutant in the waste can be classified under one of the following headings:

1. Acidity or alkalinity
2. Suspended solids
3. Filterable solids
4. Dissolved solids
5. Temperature

Various combinations of the above types of pollution may occur in an inorganic chemical waste. Care must be taken when discussing these types of pollutants that the correct references are used, e.g., the total dissolved solids (TDS) referred to here refers to TDS after neutralization when there is no excess acidity or alkalinity, since a large amount of TDS may be removed in the process of neutralization.

The ranges of the values for pollutants found from the industry were as follows:

Process Water

Flow rate	0.5 mgd to 50 mgd
Acidity	200 mg/l (as $CaCO_3$) to 20,000 mg/l
Suspended solids	0-500 mg/l
Dissolved solids	1000-150,000 mg/l

Cooling Water

Flow rate	Up to 150 mgd
Temperature range	140°F-180°F

It is evident from many studies of distribution of pollutant concentration with flow rate that the combination of high pollutant load with high flow rate is improbable. Thus, generally with high process water flow rates such as 50 mgd, the probability of having a TDS of 150,000 mg/l is remote. For this reason, an envelope of extreme values

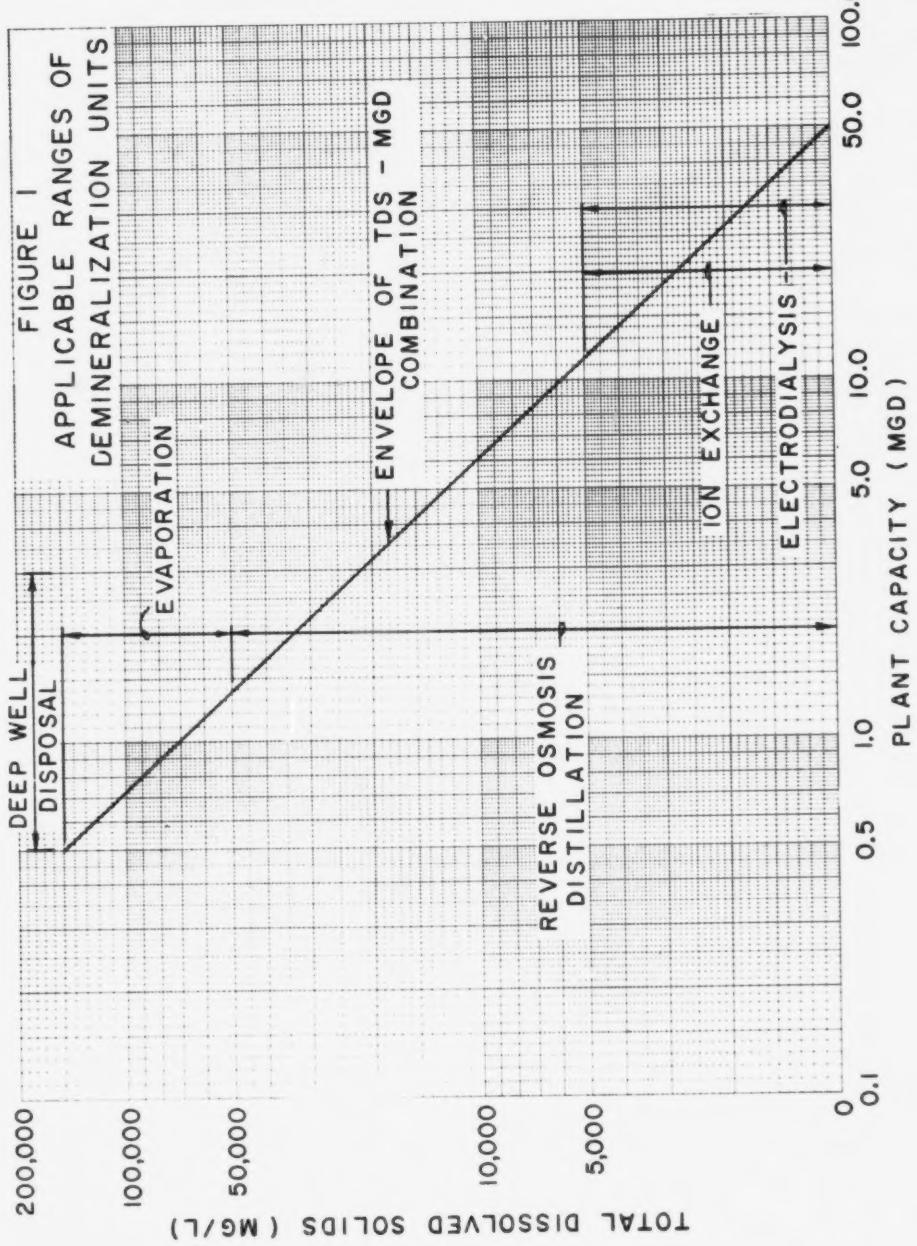


FIGURE 1
APPLICABLE RANGES OF DEMINERALIZATION UNITS

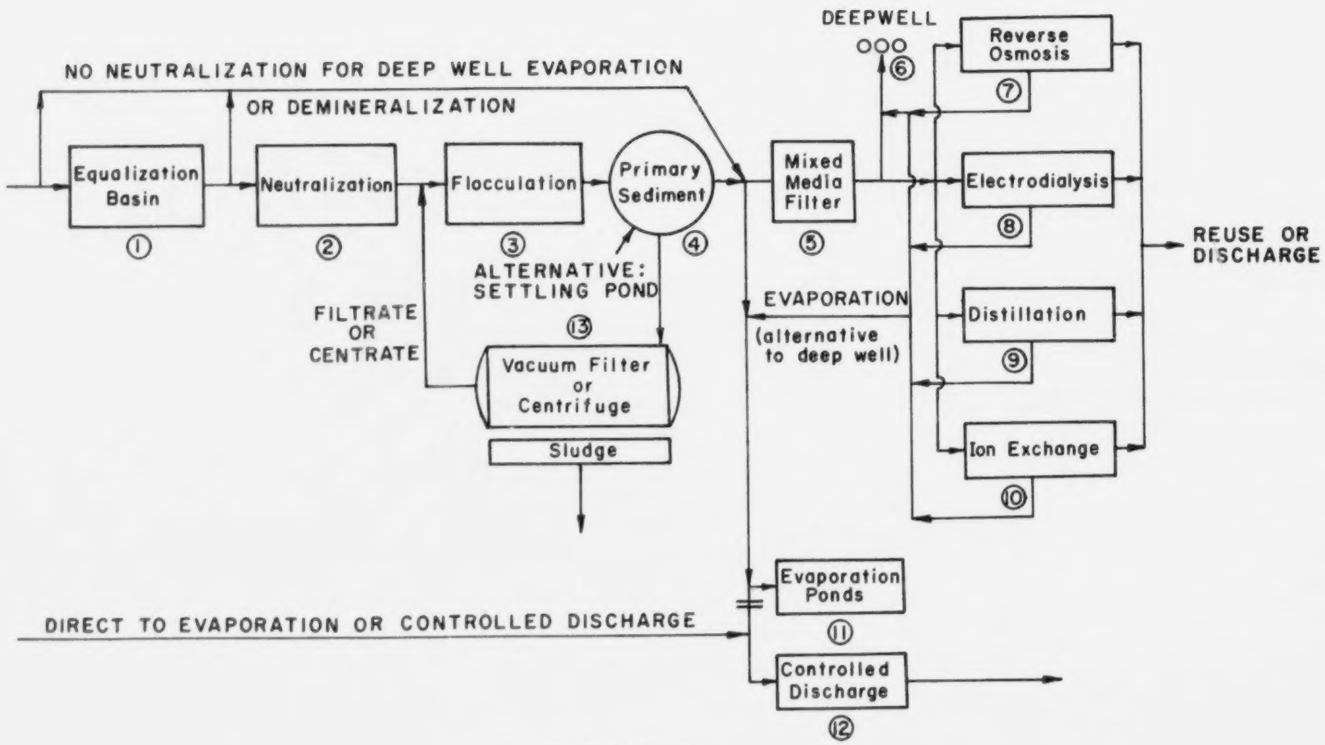

NO NEUTRALIZATION FOR DEEP WELL EVAPORATION
OR DEMINERALIZATION
Equalization Basin
①
Neutralization
②
Flocculation
③
Primary Sediment
④
ALTERNATIVE: SETTLING POND
FILTRATE OR CENTRATE
⑬
Vacuum Filter or Centrifuge
Sludge
Mixed Media Filter
⑤
DEEPWELL
⑥
Reverse Osmosis
⑦
Electrodialysis
⑧
Distillation
⑨
Ion Exchange
⑩
REUSE OR DISCHARGE
EVAPORATION
(alternative to deep well)
Evaporation Ponds
⑪
DIRECT TO EVAPORATION OR CONTROLLED DISCHARGE
Controlled Discharge
⑫

FIGURE 2

SCHEMATIC LAYOUT OF TREATMENT PLANT FOR WASTES FROM THE INORGANIC CHEMICAL INDUSTRY SHOWING VARIOUS POSSIBLE COMBINATIONS OF UNITS

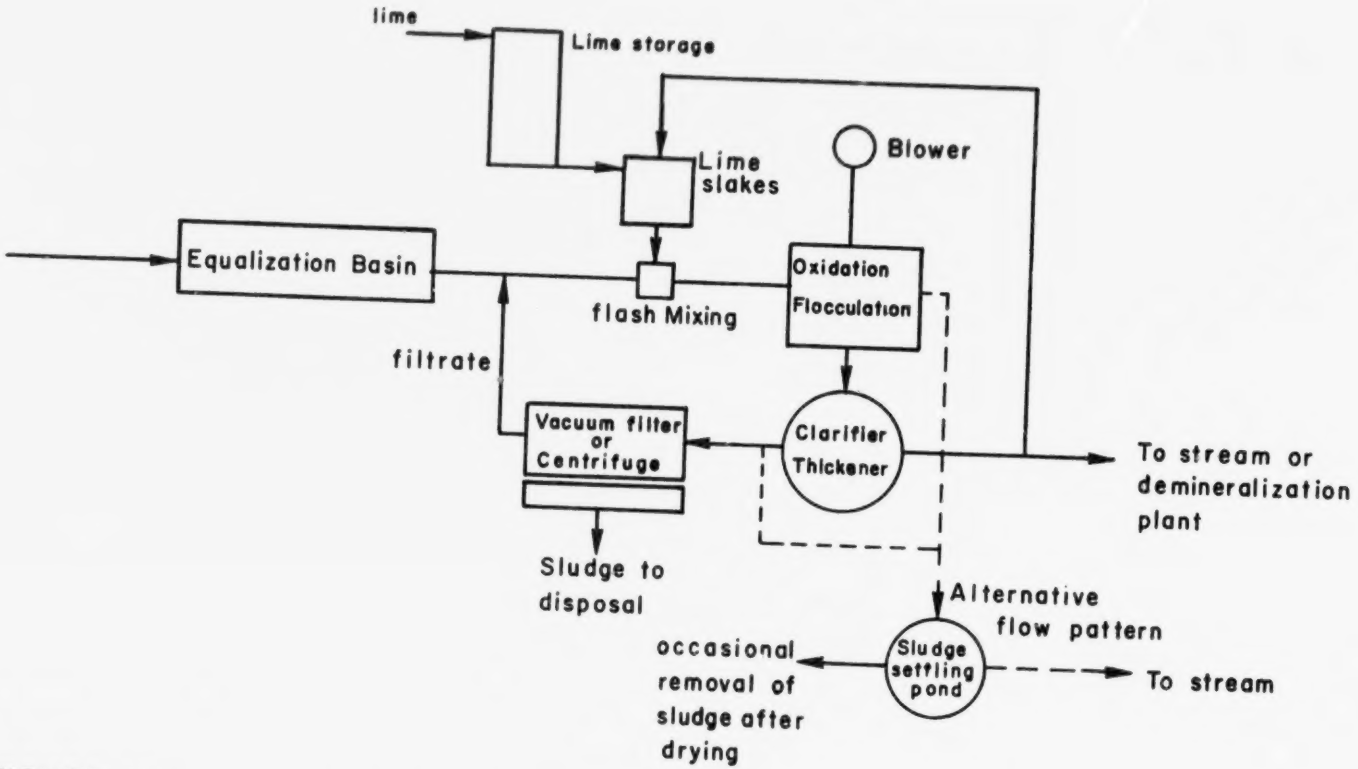

lime
Lime storage
Lime slakes
Blower
Equalization Basin
flash Mixing
Oxidation Flocculation
filtrate
Vacuum filter or Centrifuge
Clarifier Thickener
To stream or demineralization plant
Sludge to disposal
Alternative flow pattern
occasional removal of sludge after drying
Sludge settling pond
To stream

FIGURE 3
FLOW SHEET FOR NEUTRALIZATION PLANT

of TDS and flow rate that have been considered for cost calculations are shown in Figure 1. The following combinations within the triangle and values of acidity were chosen for this cost study:

Flow rate	0.5, 1.0, 10.0, 50.0 mgd
Acidity	500, 1000, 20,000 mg/l (as $CaCO_3$)
Suspended solids	100, 500 mg/l
TDS	3000, 30,000, 150,000 mg/l

The flow sheet suggested for analysis is shown in Figure 2. When neutralization of the acidity is not required, the neutralization plant will be bypassed. At low acidities and a low flow rate, it may be more economical to eliminate neutralization if high TDS must be removed anyway. This will depend on the cost structure of the various units, the quantities of waste, the use to which product wastes may be used, the economy of brine disposal versus solids disposal, and other such considerations.

The neutralization plant suggested for cost analysis is shown in Figure 3, and discussed in Appendix E under the heading of neutralization. The plant included aeration flocculation to precipitate ferrous and other metal ions. The costs are shown in Table I.

The removal of TDS in any of the five units, i.e., deep well disposal, reverse osmosis, electrodialysis, distillation, or ion exchange will require filtration of the liquid as a pretreatment.

All of the last four processes that were considered will produce brine. The concentration of brine produced will depend first, on the process used, but also on the cost of brine disposal and on the possible market value of the usable water produced.

For this study, it was assumed that all brine produced will be disposed of in deep wells or at a similar cost. Other disposal methods include disposition to the ocean, solar evaporation ponds, and evaporation ponds that use applied heat. The process used depends on the location and the brine concentration, as well as the cost of brine disposal. These factors are too unpredictable to be included in a study and the costs are given based on the above assumptions.

TABLE I

TREATMENT LEVEL I
NEUTRALIZATION COSTS INCLUDING EQUALIZATION AND SLUDGE DEWATERING

Flow mgd	Acidity mg/l	SS mg/l	Capital Cost $1000	Operating Cost ¢/1000 gal
0.5	500	100	120.0	15
0.5	500	500	145.0	20
0.5	1,000	100	184.0	27
0.5	1,000	500	190.0	29
0.5	20,000	100	514.0	108
0.5	20,000	500	514.0	108
1.0	500	100	183.0	14.5
1.0	500	500	236.0	25
1.0	1,000	100	300.0	26
1.0	1,000	500	320.0	26
1.0	20,000	100	807.0	103
1.0	20,000	500	807.0	103
10.0	500	100	1,120.0	11
10.0	500	500	1,290.0	12.5
10.0	1,000	100	1,540.0	18
10.0	1,000	500	1,640.0	20
50.0	500	100	3,420	10.5
50.0	500	500	3,980	11

NOTE: Costs based on the sum of unit processes 1, 2, 3, and 4 in Figure 1.

TABLE II

TREATMENT LEVEL II
DEMINERALIZATION COSTS INCLUDING PREFILTRATION AND BRINE DISPOSAL

Flow mgd	TDS mg/1	Total Product Water @ 500 mg/1 mgd	Brine Disposal mgd	CAPITAL COSTS					OPERATING COST			
				Filtration $1000	Demineralization Process No.	Demineralization Cost $1000	Brine Disposal Cost $1000	Total Cost +35%	Filtration (¢/ 1000 gal)	Demineralization (¢/1000 gal)	Brine (¢/1000 gal)	Total Cost (¢/1000 gal)
0.5	3,000			66	6	430	-	670	8.5	35.0	-	43.5
		0.35	0.15	66	7	640	360	1,439	8.5	40.0	18.0	66.5
		0.25	0.25	66	8	455	398	1,240	8.5	65.0	24.0	97.5
		0.47	0.03	66	10	1,700	190	2,551	8.5	25.0	16.0	49.5
				-	11 1/	40	-	40		5.0		5.0
0.5	30,000	0.45	0.05	66	9	806	388	1,701	8.5	98.0	16.0	122.5
				66	6	430		670	8.5	35.0	-	43.5
		0.167	0.33	66	7	784	412	1,704	8.5	75.0	29.0	112.5
		-		-	11	40		40		5.0		5.0
0.5	150,000	0.25	0.25	66	9	806	397	1,713	8.5	98.0	24.0	130.5
		-		66	6	430		670				43.5
		-		-	11	40		40				5.0
1.0	3,000	-		102	6	290		529	7.0	25.6		
		0.75	0.25	102	7	1,120	397	2,185	7.0	31.0	13.5	51.5
		0.50	0.50	102	8	896	431	1,929	7.0	54.0	18.3	79.3
		0.95	0.05	102	10	3,020	360	4,700	7.0	33.3	8.5	48.8
		-		-	11	100		75	-			5.0
	30,000	0.9	0.1	102	9	1,610	370	2,810	7.0	85.0	11.0	103.0
		0.33	0.67	102	7	1,340	447	2,550	7.0	50.0	20.6	77.6
		0.50	0.50	102	9	1,610	430	2,892	7.0	85.0	18.3	110.3
10.0	3,000	7.5	2.5	450	7	6,700	740	10,651	3.0	18.5	4.5	26.0
		5.0	5.0	450	8	6,400	925	10,496	3.0	38.0	8.0	49.0
		8.0	2.0	450	9	9,070	646	13,724	3.0	38.0	3.0	44.0
		9.5	0.5	450	10	14,800	430	21,160	3.0	30.0	1.0	34.0
				-	11	410	-	410	-	5.0	-	5.0
10.0	30,000	3.3	6.7	450	7	8,400	1,200	13,567	3.0	25.0	10.0	38.0
		0.50	0.50	450	9	9,070	925	14,100	3.0	38.0	8.0	49.0
50.0	3,000	45.0	5.0	1,350	7	29,100	925	42,356	2.0	15.0	2.0	19.0
		45.0	5.0	1,350	9	34,700	925	49,920	2.0	22.0	2.0	26.0

1/ For evaporation ponds, consider only those states or areas where the evaporation rate is twice the average annual rainfall. Consider land value a nominal $100/acre. Capital costs in thousand dollars.

The literature was searched for the amount of brine produced by the desalting units under "normal" operating conditions. Assumptions were made based on this information and the quantities used are shown in Table II, which presents the capital and operating costs for various combinations of capacities and processes. Available data usually refers to brine production as a by-product of potable water production and not of waste treatment as such. For potable water production, the disposal of brine is of secondary importance.

Where land is available and the evaporation rate exceeds the average annual rainfall by a sufficient margin, solar evaporation ponds will be an economical treatment method that will not require pretreatment. Operating costs will also be low.

In the regions of regular (as compared with seasonal) rainfall, it may be more economical to store the waste in lagoons and discharge to the stream only at sufficiently high stream flow rates to provide the necessary dilutions. This method is limited to a small number of locations in the country. The size of the ponds will be determined by the flow rate and variance of the stream flow, the TDS content of the stream and the later use of the stream. It is difficult to base a cost function on these factors and for this reason, only the method is shown.

Cooling water would normally need only to be cooled down sufficiently so as not to raise the stream temperature unduly. Cooling towers may be constructed based on the mean low flow condition in summer or cooling ponds may be used if land is cheap.

The calculated costs are summarized in two separate tables mentioned in the foregoing. Table I considers neutralization for Treatment Level I only, and Table II considers the dissolved solids removal and brine disposal costs of waste treatment at Treatment Level II.

CHAPTER X

COSTS VERSUS EFFLUENT QUALITY RELATIONSHIPS

The data from the survey of 59 plants was not sufficiently complete in regard to effluent quality to construct any statistically significant relationship between numbers of plants, and effluent quality parameters such as acidity, suspended solids and dissolved solids.

The methods of treatment currently employed by the inorganic chemical industry, as previously discussed, are quite limited in number and, in general, involve as a group (1) equalization, (2) neutralization, (3) flocculation, (4) sedimentation, and (5) sludge dewatering. This combination then is judged to account for the typical situation and to be equivalent to approximately 27% level of treatment, the reported average industry level.

The nature of the waste substances, inorganic soluble salts, and the treatment processes available to reduce or remove such salts is such that there are, practically speaking, no intermediate levels of treatment. That is to say, treatment for removal of dissolved salts, if applied at all, produces a quality of effluent water equivalent or better than plant influent supply water. An increase in the level of treatment of inorganic chemical plant effluents thus goes in one step from the 27% level involved in neutralization and suspended solids removal to 100% removal of the contaminants. For design purposes, demineralization effluent quality is set at 500 mg/l.

On the basis of the range of volumes of plant effluents and the foregoing considerations of only two levels of treatment, a series of likely design combinations was constructed, one for each level and the capital and operating costs determined. Table I in Chapter IX presented the cost data for Treatment Level I which, as previously mentioned, is judged equivalent to 27% removal. Table II in Chapter IX presented the cost data for Treatment Level II which represents 100% removal with ultimate disposal of the residues. Figure 2 in Chapter IX is a schematic diagram showing the generalized layout for treatment of water from the inorganic chemical industry. The numbers identifying each unit process correspond to the unit process numbers in Tables I and II. Note from Figure 2 in Chapter IX that the brine from the demineralization processes is taken to deep well disposal or to solar evaporation alternatively. Figure 1 in Chapter IX shows the applicable ranges of the alternative demineralization units employed in the construction of Table II data.

An examination of the information shown in the aforementioned Tables I and II of Chapter IX, coupled with a judgment as to the typical level of wastes to be encountered, leads to the selection of 1000 ppm acidity and 100 ppm suspended solids as representative of present practice to establish the basis of industry cost projections covered in Chapter XI for Treatment Level I. Similarly, 3000 ppm TDS is judged representative of wastes for application of Treatment Level II. In this latter connection, the capital and operating costs for demineralization process No. 7 reverse osmosis, were chosen for projection purposes even though simple deep well disposal is clearly lower in both costs.

It is believed that any generalization developed based upon wide use of large volume deep well disposal for Treatment Level II would be misleading since such general application of deep wells is considered impractical.

CHAPTER XI

PROJECTED INDUSTRY COSTS

According to the U.S. Census Bureau's 1963 publication, Water Use in Manufacturing, inorganic chemical plants reported annual water intake volumes as shown in Table I.

TABLE I

NUMBERS OF INORGANIC CHEMICAL PLANTS BY WATER INTAKE VOLUME-1963 (1)

		INTAKE VOLUMES millions of gallons per year				
SIC No.	Total	less than 1	1-9	10-19	20-99	more than 100
2812	38	4	2	1	2	29
2813	421	197	106	36	33	49
2816	76	32	13	4	7	20
2819	524	189	98	39	60	138
2851	1224	981	162	28	38	15
2871	241	104	50	24	32	31
2879	253	218	23	2	7	3
2892	58	28	4	5	4	17
TOTAL	2835	1753	458	139	183	302

(1) U.S. Census Bureau, Census of Manufactures-1963, "Water Use in Manufacturing"

Water discharges from large plants (intakes of more than 20 million gallons per year) are given in Table II.

TABLE II

WATER DISCHARGES FROM LARGE INORGANIC CHEMICAL PLANTS-1963 (1)

SIC No.	Total Discharge (10^9 gal/yr)	Discharge to Municipal Sewers (10^9 gal/yr)	Percent to Sewers
2812	509	21	4.2
2813 3/	10.4 1/	4.2	40.2 2/

TABLE II (cont.)

SIC No.	Total Discharge (10^9 gal/yr)	Discharge to Municipal Sewers (10^9 gal/yr)	Percent to Sewers
2816	100	11	11.0
2819	447	13	2.9
2851	5	3	60.0
2871	89	0.5	-
2879	1	0.5	-
2892	27	0.5	-

1/ Estimated from O_2 and N_2 production, use of 13 gal. per lb., and use rate of 7
2/ Estimated by Research Engineering Associates
3/ Oxygen and nitrogen only

(1) U.S. Census Bureau, ibid

Assuming that all plants having intakes of less than 20 million gallons per year discharge to municipal sewers, the total industry discharge to municipal sewers in 1963 is estimated to have been 48.0 billion gallons. Discharges from large plants to other than municipal sewers are given in Table III.

TABLE III

LARGE INORGANIC CHEMICAL PLANT DISCHARGES
OTHER THAN TO MUNICIPAL SEWERS-1963 (1)

SIC No.	No. of Plants	Discharge 10^9 gal/yr	Average Discharge 10^9 gal/yr
2812	31	488	15.74
2813	82 1/	6.2 2/	-
2816	27	89.0	3.29
2819	198	434	2.19
2851	53	2.0	0.03
2871	63	88.5	1.40
2879	10	0.5	0.05
2892	21	26.5	1.26
TOTAL	485	1134.7	2.33

1/ All industrial gases
2/ Oxygen and nitrogen plants only

(1) U.S. Census Bureau, ibid

Water intakes and usages by purpose are given in Table IV.

TABLE IV

LARGE INORGANIC CHEMICAL PLANT INTAKES AND USAGE, BY PURPOSE, 1963 (1)

	Billions of Gallons per Year					
SIC No.	Total Intake	Process	Cooling	Other	Gross Use	Use Rate
2812	528	16	478	35	628	1.19
2813 1/	21	-	-	-	146	7.0
2816	91	-	-	-	112	1.23
2819	499	74	392	33	1312	2.63
2851	5	1	3	1	8	1.6
2871	113	32	60	22	217	1.92
2879	2	-	-	-	8	4.0
2892	28	2	24	3	35	1.25
TOTAL	1287	-	-	-	2466	1.91

1/ Oxygen and nitrogen plants only

(1) U.S. Census Bureau, ibid

Assuming that contaminated wastewaters will be equivalent to that withdrawn for process and other non-cooling purposes, and that percentage disappearances are constant for all purposes, the total of such wastewaters for large plants in the industry in 1963 is estimated to have been 211.8 billion gallons to other than municipal sewers. The average contaminated wastewater discharge from large plants to other than municipal sewers is thus estimated to have been 1.196 mgd. The average discharge to municipal sewers from large plants is estimated to have been 0.303 mgd, and from small plants 6122 gpd.

Numbers of plants, values of shipments, and price indexes for the inorganic chemical industry in 1958 and 1963 are given in Table V.

TABLE V

THE INORGANIC CHEMICAL INDUSTRY, 1958 AND 1963

SIC No.	1963 No. of Plants Total	1963 No. of Plants +20 Emp.	1963 Val. of Ship. ($1000)	1963 Price Index '57-59=100	1958 No. of Plants +20 Emp.	1958 Val. of Ship. ($1000)
2812	37	34	523,944	94.8	32	425,431
2813	460	148	387,912	94.8	178	262,581
2816	97	52	486,464	91.1	57	412,011
2819	678	326	3,008,028	94.8	301	2,146,254
2851	1779	650	2,281,967	91.1	600	1,753,923
2871	279	198	734,314	99.9	207	611,103 1/
2879	329	108	453,521	99.9	101	347,628
2892	67	47	180,817	99.0	58	169,699

1/ Estimated from value added by manufacturing and 1963 "Water Use In Manufacturing" data.

These data are shown in terms of 1958 prices in Table VI.

TABLE VI

NUMBER OF PLANTS AND VALUE OF SHIPMENTS, 1958 PRICES

	1963		1958	
SIC No.	No. Plants more than 20 Emp.	Val. of Ship. ($1000-'58)	No. Plants more than 20 Emp.	Val. of Ship. ($1000)
2812	34	552,684	32	425,431
2813	148	409,190	178	262,581
2816	52	533,989	57	412,011
2819	326	3,173,025	301	2,146,254
2851	650	2,504,903	600	1,753,923
2871	198	735,049	207	611,103
2879	108	453,975	101	347,628
2892	47	182,613	58	169,699

Values of shipments in 1966 are given in Table VII in terms of current and 1958 prices.

TABLE VII

VALUES OF INORGANIC CHEMICAL SHIPMENTS, 1966

SIC No.	Val. of Ship., '66 ($1000)	Price Index '57-59=100	Val. of Ship., '66 ($1000-'58)
2812	625,870	95.7	653,992
2813	493,779	95.7	515,966
2816	573,598	90.1	636,624
2819	3,658,633	95.7	3,823,023
2851	2,709,788	90.1	3,007,534
2871	947,216	104.4	907,295
2879	672,788	104.4	644,433
2892	236,139	100.3	235,433

Values of shipments in 1968 and 1969 are given in Table VIII.

TABLE VIII

VALUES OF INORGANIC CHEMICAL SHIPMENTS, 1968 AND 1969

	1968			1969		
SIC No.	Val. of Ship. ($1000)	Price Index ('57-59=100)	Val. of Ship. ($1000-'58)	Val. of Ship. ($1000)	Price Index ('57-59=100)	Val. of Ship. ($1000-'58)
2812	891,000	98.4	905,488	955,000	98.4	970,528
2813	630,000	98.4	640,244	665,000	98.4	675,813
2816	658,000	92.2	713,666	696,000	92.2	754,881
2819	4,386,000	98.4	4,457,317	4,510,000	98.4	4,583,333
2851	3,255,000	92.2	3,530,369	3,445,000	92.2	3,736,443
2871	1,089,000	100.3	1,085,743	1,089,000	100.3	1,085,743
2879	780,000	100.3	777,667	830,000	100.3	827,517
2892	501,000	110.0	455,455	517,000	110.0	470,000

In Figure 1, the number of plants with more than 20 employees is plotted against the values of shipments in 1958 dollars. Using the data in Figure 1 and assuming that (1) the number of plants having water intakes of over 20 million gallons, (2) those having more than 20 employees, and (3) the total number of plants will remain in the 1963 ratio, numbers of plants are estimated by year in Table IX.

TABLE IX

NUMBERS OF PLANTS IN THE INORGANIC CHEMICAL INDUSTRY

Year	Val. of Ship. ($1000-'58)	No. of Plants (more than 20 Emp.	No. of Plants (more than 20 mil. gal/yr)	No. of Plants (Total)
1958	6,128,630	1534	476	2782
1963	8,545,458	1563	485	2835
1966	10,424,300	1586	492	2877
1968	12,565,949	1613	501	2926
1969	13,104,261	1620	503	2938

In 1963, the value of shipments of oxygen and nitrogen totaled $202 million dollars, or 52% of the total value of industrial gases. In 1967, the value cf oxygen and nitrogen was $282 million dollars, or 50.2% of the total for SIC 2813 (Industrial Gases). Assuming that the numbers of plants are in the ratio of the values of shipments, the number of plants in the industry as defined by this study are estimated as in Table X.

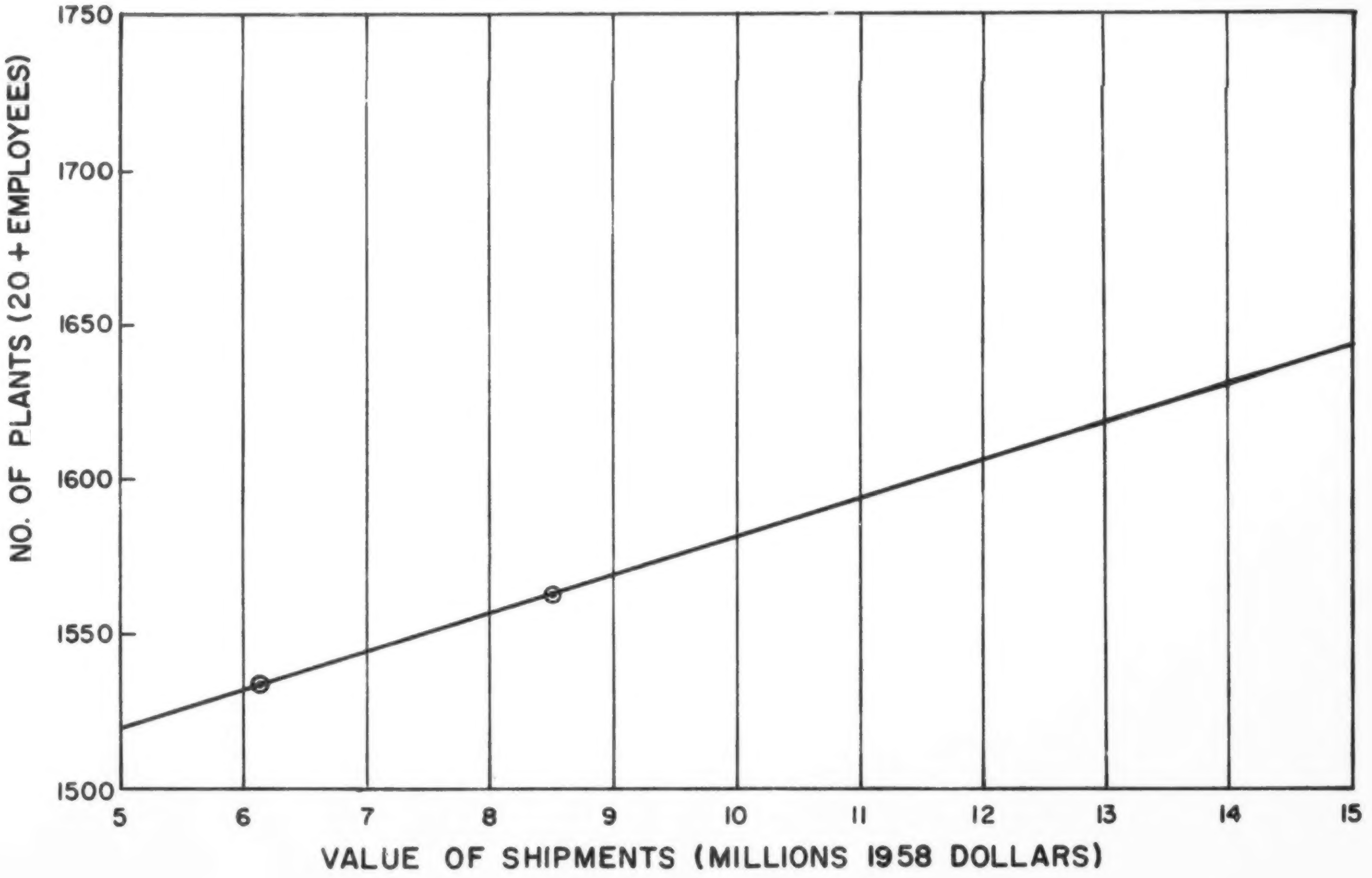
TABLE X

NUMBERS OF INORGANIC CHEMICAL PLANTS FOR STUDY PURPOSES

	Number of Plants [1]	
Year	Total	+20 mil. gal/yr
1963	2633	446
1966	2675	453
1968	2724	462
1969	2736	464

[1] Nitrogen and oxygen only in SIC 2813

FIGURE 1-NO. OF PLANTS VERSUS VALUE OF SHIPMENTS



In Table XI, productions of inorganic chemicals are given for 1968 and projected by year through 1974.

TABLE XI

PROJECTED PRODUCTION OF INORGANIC CHEMICALS, 1968-1974
(millions of tons)

SIC No.	1968	1969	1970	1971	1972	1973	1974
2812	24	25	26	28	30	32	34
2813 1/	17.5	20.1	23.7	28.5	34.3	40.8	47.9
2816	1.20	1.25	1.29	1.37	1.44	1.51	1.59
2819	70	72	74	77	80	84	88
2851 2/	3.51	3.74	3.93	4.16	4.41	4.68	4.96
2871	41.5	41.0	42.3	43.9	46.1	48.0	49.9
2879	0.20	0.20	0.19	0.18	0.18	0.17	0.15
2892 3/	0.98	1.04	1.08	1.11	1.15	1.20	1.27

1/ From Chemical and Engineering News 1968 production and Resource Engineering Associates projections

2/ From Resource Engineering Associates projection and sp. gr.=1.0

3/ From 1963 production and values and Resource Engineering Associates projections

Production in the industry, numbers of plants, and waste discharges are projected from the above data in Table XII. Numbers of plants are estimated as in proportion to total industry production and in the ratios of plant sizes and SIC distributions as in 1963. Eighty five percent of the total production is assumed to have been produced in large plants, as is indicated by the plant capacity data in Appendix B.

TABLE XII

THE INORGANIC CHEMICAL INDUSTRY, 1963-74 1/

	1963	1968	1969	1970	1971	1972	1973	1974
No. of Plants, Total	2633	2724	2736	2754	2780	2810	2842	2876
No. of Small Plants 2/	2187	2262	2272	2288	2309	2334	2361	2389
No. of Large Plants 3/	446	462	464	466	471	476	481	487
Production Total (billion lbs)	-	317.8	328.7	345.0	368.4	395.2	424.7	455.5
Production, Large Plants (bil. lbs)	-	270.1	279.4	293.3	313.1	335.9	361.0	387.2
Production, Small Plants (bil. lbs)	-	47.7	49.3	51.7	55.3	59.3	63.7	68.3
Municipal Sewer Discharges (billion gal)	59.0	86.7	90.0	94.3	100.5	107.6	115.4	123.6
Large Plants (billion gal)	53.7	78.9	81.9	85.8	91.5	98.0	105.2	112.7
Small Plants (billion gal)	5.3	7.8	8.1	8.5	9.1	9.7	10.4	11.1
Wastewater, Not to Sewers, Large Plants (bil. gal)	211.8	311.1	322.9	338.4	360.7	386.3	414.5	443.9
Cooling Water, Not to Sewers, Large Plants (bil. gal)	922.9	1356	1407	1475	1572	1684	1807	1935
Gross Water Use, Large Plants (bil. gal)	2466	3625	3763	3947	4211	4514	4848	5197
Value of Shipments, Total (bil. 1958 $)	8.545	12.566	13.104	-	-	-	-	-

1/ Based upon 1963 water use data and projected production
2/ <20 million gallons per year
3/ >20 million gallons per year

The data in Table XII are based upon the water uses reported in 1963 and discharges are estimated from gross water uses based upon projected production. In 1963, large plants in the inorganic chemical industry used (including recirculation) 2466 billion gallons of water for all purposes and discharged 1134.7 billion gallons, taking in 1287 billion gallons. The entire chemical industry (SIC 28) reported a use of 7577 billion gallons that year; the inorganic chemical industry thus used about 32.5% of the total. A 1967 survey of the chemical industry by the Manufacturing Chemists Association (2) indicated a gross water use of 8340 billion gallons that year. These data and the data in Table XII indicate water uses in the inorganic chemical industry of 2711 and 3393 billion gallons per year, respectively. Inorganic chemicals have shown a long term decrease in percentage of the overall chemical market from 49.5% in 1958 to 40% in 1968.

Data from the 1958 and 1963 Census of Manufactures and from the 1967 MCA survey are shown in Table XIII. These data generally apply to large plants in the chemical industry.

(2) "Toward a Clean Environment," Manufacturing Chemists Association, 1967

TABLE XIII

WATER USE DATA, 1958-67

	1958 1/	1963 1/	1967 2/
CHEMICALS & ALLIED PRODUCTS:			
Intake, bil. gal.	3240	3889	4269
Gross Use, bil. gal.	5225	7577	8340
Discharges, bil. gal.	3061	3662	4085
Use Rate	1.61	1.95	1.95
Discharges as % of Use	58.5	48.3	48.9

TABLE XIII (cont.)

	1958 1/	1963 1/	1967 2/
INORGANIC CHEMICALS:			
Intake, bil. gal.		1287	
Gross Use, bil. gal.		2466	
Discharges, bil. gal.		1134.7	
Use Rate		1.92	
Discharges as % of Use		46.0	

1/ U.S. Bureau of Census, 1963 Census of Manufactures, Water Use in Manufacturing
2/ Ref (2) MCA Survey, ibid

Table XIV shows projections of water uses and discharges which incorporate all of the above data from Tables XII and XIII. The data in Table XIII indicate that 1963 use rates and discharge ratios may be used with confidence since no significant changes are indicated. As indicated above, the water use figures from Table XII have been revised to incorporate the 1967 survey data, using the average water use in 1967 of 3059 billion gallons calculated from use increases 1958-63, and a linear extrapolation from 1963 to 1967 based upon values of shipments, and the 1967 indicated use.

Data from the 1967 MCA survey of the chemical industry are given in Table XV and ranges of plant capacities in the inorganic chemical industry are shown in Table XVI. Table XVI indicates an average plant capacity of 0.783 billion pounds per year and a median capacity of 0.319 billion pounds per year. This compares favorably with the 1969 average capacity in Table XIV of 0.602 billion pounds per year. The data in Table XV indicate an average discharge from large plants of wastewater to other than municipal sewers of 0.657 billion gallons per year per plant in 1967 for the chemical industry as a whole. Table XIV and figures from the organic chemical industry study (3) made in 1968 by this research team indicate an average wastewater discharge of 0.755 billion gallons per year per plant in 1968 from large plants. These figures show an agreement within expected limits of accuracy.

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(3) Projected Wastewater Treatment Costs in the Organic Chemicals Industry, January, 1969, Federal Water Pollution Control Administration, United States Department of the Interior

TABLE XIV

THE INORGANIC CHEMICAL INDUSTRY, 1963-74 1/

	1963	1968	1969	1970	1971	1972	1973	1974
Total No. of Plants	2633	2724	2736	2754	2780	2810	2842	2876
No. of Small Plants	2187	2262	2272	2288	2309	2334	2361	2389
No. of Large Plants	446	462	464	466	471	476	481	487
Production:								
Total (billion lbs.)	-	317.8	328.7	345.0	368.4	395.2	424.7	455.5
Large Plants (billion lbs.)	-	270.1	279.4	293.3	313.1	335.9	361.0	387.2
Small Plants (billion lbs.)	-	47.7	49.3	51.7	55.3	59.3	63.7	68.3
Municipal Sewer Discharges:								
Total (billion gal)	59.0	76.7	79.3	83.3	88.9	95.4	102.5	109.9
Large Plants (billion gal)	53.7	69.8	72.2	75.8	80.9	86.8	93.3	100.0
Small Plants (billion gal)	5.3	6.9	7.1	7.5	8.0	8.6	9.2	9.9
Large Plant Discharges & Use:								
Wastewater, Not to Sewers (bil. gal)	211.8	275.4	284.9	298.9	319.2	342.4	367.9	394.6
Cooling Water, Not to Sewers (bil. gal)	922.9	1200	1241	1303	1391	1492	1603	1720
Gross Water Use (bil. gal)	2466	3207	3317	3481	3717	3987	4284	4595
Large Plants, Average Data:								
Production, bil lbs/yr/plant	-	0.585	0.602	0.629	0.665	0.706	0.751	0.795
Wastewater, bil gals/yr/plant	0.475	0.596	0.614	0.641	0.678	0.719	0.765	0.810

1/ Ref (1) U.S. Census Bureau, ibid
Ref (2) Manufacturing Chemists Association 1967 Survey, ibid

TABLE XV

1967 MCA SURVEY DATA
THE CHEMICAL INDUSTRY (2)

No. of Plants	987
Capital Investment in Wastewater Treatment through 1966	$385,268,000
Capital Investment in Wastewater Treatment, 1962-1966	$140,640,000
Capital Investment in Wastewater Treatment, 1967-1971	$235,700,000
Annual Operating Cost, 1967	$59,638,000
Water Withdrawals	11.696 bil. gal/day
Water Used	22.848 bil. gal/day
Discharge to Surface Waters:	
Cooling Water	9.224 bil. gal/day
Process Wastewater	1.777 bil. gal/day
Discharge to Public Sewers:	
Cooling Water	0.078 bil. gal/day
Process Wastewater	0.114 bil. gal/day
Inorganic Waste Discharges:	
To Surface Waters:	
Dissolved	135.3 mil. lbs/day
Undissolved	11.65 mil. lbs/day
To Public Sewers:	
Dissolved	2.156 mil. lbs/day
Undissolved	0.192 mil. lbs/day
Total Discharged	149.3 mil. lbs/day
Total Discharged with No Treatment	205.1 mil. lbs/day

(2) Manufacturing Chemists Association 1967 Survey, ibid

TABLE XVI

RANGES OF CHEMICAL PLANT PRODUCTION CAPACITIES [1]

Product	Capacity Range, tons/day
Caustic Potash	13.7 - 98.6
Caustic Soda	300 - 7800
Chlorine	180 - 7050
Soda Ash	205 - 10274
Titanium Dioxide	49.3 - 474
Ammonium Nitrate	30.1 - 1164
Nitric Acid	43.8 - 1096
Phosphoric Acid	47.4 - 1342
Phosphorous	16.4 - 389
Sodium Dichromate	41.1 - 247
Sodium Sulfate	21.9 - 753
Superphosphate	63.0 - 959
Ammonium Phosphate	19.2 - 630
Potash	27.4 - 1699
Calcium Carbide	54.8 - 822
Hydrofluoric Acid	27.4 - 137
Sodium Sulfite	8.2 - 397

[1] Industry Product Profiles, Appendix C

Numbers of plants in the chemicals and allied products industries in 1963 are shown in Table XVII by industry segments and by intake water volumes.

TABLE XVII

NUMBERS OF PLANTS IN THE CHEMICAL INDUSTRY, 1963

	Large Plants (more than 20 mil. gal)	Small Plants (less than 20 mil. gal)
Industry Total [1]	1129	6382
Organic Chemicals Industry [2]	211	550
Inorganic Chemicals Industry [3]	446	2187
Other Industry Segments	472	3645

1/ 1963 Census of Manufactures
2/ Ref (3) FWPCA Organic Chemicals Industry, ibid
3/ Present study

Data from the 1967 survey of the chemical industry by the Manufacturing Chemists Association as shown in Table XV are extended on an annual basis and given in Table XVIII.

TABLE XVIII

CHEMICAL INDUSTRY SURVEY DATA, 1967 (2)

No. of Plants	987
Total Employment	393,657
Capital Investment in Wastewater Treatment through 1966	$385,268,000
Capital Investment in Wastewater Treatment, 1962-1966	$140,640,000
Capital Investment in Wastewater Treatment Projected, 1967-1971	$235,700,000
Annual Operating Cost, 1967	$59,638,000
Annual Manpower Requirements, 1967	2096.1 man-years
Annual Water Intake, bil. gal.	4269
Annual Water Use, bil. gal	8340
Use Rate	1.95
Plant Effluents:	
Cooling Water, to Public Sewers, bil. gal	28.33
Process Wastewater, to Public Sewer, bil. gal.	41.65
Cooling Water, to Surface Waters, bil. gal.	3367
Process Wastewater, to Surface Waters, bil. gal.	648.6
Total Effluents, bil. gal	4085
Contaminants in Effluents to Surface Waters:	
Dissolved Inorganics, mil. lbs.	49370
Undissolved Inorganics, mil. lbs.	4252
Dissolved Organics, mil. lbs.	1284
Undissolved Organics, mil. lbs.	155.5
Contaminants in Effluents to Public Sewers:	
Dissolved Inorganics, mil. lbs.	786.9
Undissolved Inorganics, mil. lbs.	70.1
Dissolved Organics, mil. lbs.	292
Undissolved Organics, mil. lbs.	74.8

TABLE XVIII (cont.)

Total Contaminants Produced:	
Inorganics, mil. lbs.	74857
Organics, mil. lbs.	4191

(2) MCA 1967 Survey, ibid

The chemical industry, other than those segments defined as "inorganic chemicals" and as "organic chemicals," includes operations producing inorganic and organic compounds which appear in effluents. Assuming (1) that process wastewaters from the inorganic chemical industry contain only inorganic contaminants, (2) that process wastewaters from the organic chemical industry contain only organic contaminants, and (3) that effluents from other segments contain proportionate amounts of each wastewater volume, the characteristics of the industry's discharge are estimated below in Table XX from the 1967 MCA survey, the 1963 census data, and the 1969 FWPCA study of the organic chemicals industry.

Table XIX shows the estimated numbers of plants and wastewater discharges in the chemical industry in 1967, based upon the above three data sources.

TABLE XIX

CHEMICAL PLANT SIZES AND DISCHARGES-1967

	Industry Segment			
	Inorganic	Organic	Other	Total
Numbers of Plants:				
Total	2706	833	4290	3829
Large (>20 mgy)	459	231	496	1186
Small (<20 mgy)	2247	602	3794	6643
Wastewater, Large Plants:				
Not to Sewers (bil. gal)	263	383	133	779
Discharge to Sewers (bil. gal).	73.2	78.2	70.1	221.5

TABLE XX

CHEMICAL INDUSTRY DISCHARGES-1967

	Industry Segment Discharges			
	Inorganic	Organic	Other	Total
Discharges to Public Sewers:				
Inorganics (mil. lbs)	696.5	-	333.5	1030
Organics (mil. lbs)	-	304.5	136.5	441
Discharges to Surface Waters:				
Inorganics (mil. lbs)	51429	-	13004	64433
Organics (mil. lbs)	-	1474	256	1730

Using the data in Tables XIX and XX and the MCA survey data, prorating costs and manpower requirements on the basis of wastewater discharges and relative contaminant removals, the data in Table XXI are estimated for large plants in the chemical industry in 1969.

TABLE XXI

CHEMICAL INDUSTRY COSTS AND MANPOWER-1969

	Industry Segment			
	Inorganic	Organic	Other	Total
Investment, mil. $	130.306	399.773	102.473	632.552
Operating Costs, mil. $/yr.	20.170	61.880	15.862	97.912
Manpower Use, man-years/yr.	709	2175	558	3442

Assuming, as discussed in Chapter X, that the average plant in the industry produces wastewaters containing 100 ppm suspended solids, 1000 ppm acidity and 3000 ppm dissolved solids, and that present practice as defined by the MCA survey (27% removal of contaminants) is achieved by neutralization with equalization and sludge dewatering, the following unit costs are as shown in Chapter IX for the typical plant. Reverse osmosis is the method of choice for demineralization (100% removal of contaminants) as indicated by reasonable capital and operating costs. Deep well disposal and evaporation ponds, although lower in cost, are not always applicable due to local conditions and, hence, were not shown.

% Removal Contaminants	Capital Costs $/1000 gpd	Operating Costs ¢/1000 gal
27 (SS and Acidity)	300	26.0
100 (TDS)	2185	51.5

Assume also that the capital costs involved in discharging to public sewers are those entailed in removing suspended solids and neutralizing acidity. Therefore, based upon the flows shown in Table XIV and the above assumptions on unit capital costs, the capital costs for the inorganic chemicals industry are estimated as shown in Table XXII and XXIII. The capital costs for the 27% removal level shown in 1969 thus represent the in place capital for the existing levels of treatment in the inorganic chemical industry in 1969 dollars.

TABLE XXII

CUMULATIVE INORGANIC CHEMICAL INDUSTRY CAPITAL COSTS, 1969-1974

% Removal	Costs in Millions of 1969 Dollars					
	1969	1970	1971	1972	1973	1974
27	299.3	314.1	335.4	359.8	386.6	414.7
100	1808.4	1897.5	2026.3	2173.0	2335.0	2507.0

In terms of current dollars, and using an average of 3.6% annual increase in the price level, total industry capital costs are projected in Table XXIII.

TABLE XXIII

CUMULATIVE INORGANIC CHEMICAL INDUSTRY CAPITAL COSTS, 1969-1974

% Removal	Costs in Millions of Current Dollars					
	1969	1970	1971	1972	1973	1974
27	299.3	325.4	359.9	400.1	445.4	494.7
100	1808.4	1964.0	2173.2	2416.3	2689.0	2970.0

It should be underscored that the capital costs shown in Tables XXII and in Table XXIII for 1969 are in terms of 1969 dollars. The capital costs for the chemical industry shown in Table XXI are in terms of sums spent over perhaps the preceding 30 years. Allowing for price increases over such a period of time, the costs shown in Table XXI for the inorganic segment of the industry compare well with that portion of the 1969 costs in Table XXII for the 27% level of treatment attributable to large plants. Assuming that the operating costs associated with discharges to municipal sewers at 10 cents per 1000 gpd, projected industry operating costs are given in Table XXIV in 1969 dollars and in Table XXV in current dollars.

TABLE XXIV

PROJECTED ANNUAL INORGANIC CHEMICAL
INDUSTRY OPERATING COSTS

%	Costs in Millions of 1969 Dollars					
Removal	1969	1970	1971	1972	1973	1974
27	82.0	86.0	91.9	98.6	105.9	113.6
100	157.5	165.1	176.3	189.2	203.2	218.0

TABLE XXV

PROJECTED ANNUAL INORGANIC CHEMICAL
INDUSTRY OPERATING COSTS

%	Costs in Millions of Current Dollars					
Removal	1969	1970	1971	1972	1973	1974
27	82.0	89.1	98.6	109.6	122.0	135.5
100	157.5	171.0	189.2	210.5	234.2	260.2

The plant survey data shown in Chapter VIII, based upon costs per unit of wastewater flow, indicate that the industry costs to achieve 85% removal of contaminants other than dissolved solids in large plants in 1969 are as follows:

In place capital costs =
    $223 x 978356 (1000 gpd) = $218,173,425
In place operating costs =
    $58.49 x 978356 (1000 gpd) = $57,224,042/year

Addition of the costs associated with discharges to municipal sewers by small plants show that the total industry costs for the level of treatment described can be estimated as follows:

In place capital costs =
    224.0 million dollars
In place operating costs =
    57.9 million dollars per year

The above costs would represent an overall removal of wastewater contaminants of approximately 23%, i.e., 85% removal of contaminants constituting 27% of the total in the wastewaters. Comparison of these figures with those in Tables XXII and XXIV shows good agreement and tend to support the projections made.

CHAPTER XII

QUALITATIVE MANPOWER REQUIREMENTS

Waste Treatment Manpower Structure

The effective operation and maintenance of an inorganic chemical industry waste treatment facility requires the combined efforts of many disciplines and vocations. There is a need for administrative and support services, technical management and services, treatment process operations, and equipment maintenance. The relationship of these four functional areas to waste treatment is briefly described below.

Administrative Support and Services

Managerial-level support to waste treatment is required to make decisions affecting waste treatment; to maintain cognizance over local, state, and Federal regulatory requirements; to establish organizational structures to accomplish effective waste treatment; and to supervise subordinates in the implementation of waste treatment objectives. The management staff is also responsible for preparing reports to regulatory agencies and maintaining an operational interface with such agencies. Non-professional administrative services are required in the form of supervisory personnel in the areas of engineering and laboratory support, operations, and maintenance.

Technical Management and Services

Technical services in support of waste treatment are required in three principal areas: (1) to meet day-to-day water analysis requirements necessary for effective waste treatment; (2) to handle investigations into special waste treatment problems which may arise; and (3) to design and implement modifications or additions to improve waste treatment efficiency/effectiveness. Laboratory and engineering personnel within the regular production organization of a large or medium sized plant ordinarily provide all of these services. In the case of smaller plants with limited personnel resources, consultants in waste treatment and engineering are often called upon to supplement technical staffs in dealing with special problems.

Typical chemical plants will have engineering and laboratory personnel of the following types assigned to production and research/development efforts within the plant, and draw upon on a part-time basis for support of the waste treatment facility:

	DOT [1]
Chemical Engineer	008.081
Mechanical Engineer	007.181
Analytical Chemist	022.081
Inorganic Chemist	022.081
Engineering Analyst	020.088
Laboratory Technician	029.181

[1] Dictionary of Occupational Titles

Waste Treatment Operations

Just as a treatment system can vary from a single, rather simple, process to a system with many complex individual treatment processes, the skill and knowledge requirements for competent water treatment operations vary considerably. Specific demands depend on the nature of the waste being treated and the processes comprising the treatment system.

A common situation in the chemical industries is that personnel operating the waste treatment facilities are either grossly over-trained or grossly under-trained. Professional people, such as chemical engineers, are often in charge of the waste treatment facility without a staff of properly trained personnel to direct. While there is little doubt that professionals can properly operate the facility, it is a poor utilization of their skills and training. With under-trained personnel, there is considerable risk of ineffective waste treatment and damage to treatment equipment representing a sizable capital investment, also a poor cost-effective situation. Professionals cannot devote large amounts of time to waste treatment operations without neglecting their primary mission in the chemical plant, that of efficiently producing chemical products. In a very competitive industry such as the chemical industry, there is not sufficient slack in the manpower pool to permit uneconomic use of expensive talent. The practice of assigning members of the production staff, often with little or no formal or on-the-job training, to the operations function of a treatment facility is equally unsound. The need for specially trained waste treatment operators is obvious.

The lack of training in waste treatment has not necessarily doomed past efforts to failure and, in fact, many operations personnel are quite competent without having the benefit of special training. There are two basic reasons why the lack of specially trained operators has not always spelled disaster in the treatment of chemical industry wastes. First, much of the treatment process equipment and appurtenances is very similar or identical to unit process equipment used in the production of chemicals, requiring significantly less additional skill and knowledge than would otherwise be required. Secondly, the relatively loose requirements of past years on the permissible level of contaminants have resulted in many typically marginal, uncomplicated, and easy-to-operate-and-maintain treatment systems. However, with effluent restrictions becoming increasingly more stringent, the skill and knowledge requirements for operator personnel will become more complex as more effective and complicated systems are installed. With this in mind, major emphasis in this chapter has been placed on the operator role in waste treatment as waste treatment operation will be in the near future, rather than as it now exists in the chemical industries. It is the operations function, along with an interwoven maintenance function, which will undergo dramatic change in future years, with less of an impact taking place in other functional areas.

Maintenance

Maintenance of treatment process equipment and appurtenances in the chemical industries is carried out by both the operations personnel and skilled workers in many vocational specialties. It is common practice for operations personnel to perform routine preventive maintenance while the more complicated maintenance, primarily of a corrective nature, is the responsibility of specialists drawn from the production manpower pool. For example, preventive maintenance tasks, such as lubricating pumps, are normally performed by waste treatment operator personnel while corrective maintenance, such as major repair or overhaul, is performed by a specialist in the repair of pumps. The regular maintenance staff of a typical medium or large sized chemical plant will generally encompass the following occupational areas:

	DOT
Instrument Repairman	710.281
Maintenance Mechanic	638.281
Maintenance Machinist	600.280
Water Pump Serviceman	630.281
Pipe Fitter, Maintenance	862.381
Electrician, Maintenance	829.281
Carpenter, Maintenance	860.281

The smaller chemical plants often have quite small maintenance staffs and supplement their maintenance capability through contracts with equipment manufacturers and independent maintenance firms.

Qualitative Manpower Requirements

It is obvious that critical responsibility for effective and efficient treatment of wastewater rests with the operators of the waste treatment facility. Therefore, it is the operator of the facility and the equipment for which he is responsible that govern the basic content of this chapter.

Time was not available to develop specific qualitative information for the administrative support and technical management occupations. Such development would have required augmenting existing DOT classifications with information concerning duties involving water pollution control and the type of training required.

While administrative and technical support is requisite to the effective treatment of waste in the inorganic chemical industry, the qualitative nature of these support requirements will undergo less of a change in future years than will the treatment processes and skills required for operating and maintaining them. Descriptions of the qualitative requirements for waste treatment in the chemical industry will be concentrated on operations and maintenance functions.

It is difficult to describe qualitative personnel requirements in the chemical industry in terms of specific industry segments or treatment systems. The contaminants of wastewater vary considerably between inorganic industry components and between plants producing the same products. The volume of waste and options for treatment are also quite varied, often due to geographic location of the plant and restrictions placed upon disposal of industrial wastes into municipal sewerage systems. For the sake of simplicity and clarity, qualitative personnel requirements will be considered on a treatment process basis. Just as chemical engineers look upon a chemical processing system in terms of the unit processes which comprise the system, it would appear most logical to look at manpower requirements for a treatment system in terms of the system's unit treatment components. Utilizing this approach, each of the following treatment processes has been analyzed individually to identify skill and knowledge requirements for operations and maintenance:

Chemical Addition
Equalization
Oil Removal
Sedimentation
Filtration
Reverse Osmosis
Electrodialysis
Ion Exchange
Multiple Effect Evaporation
Deep Well Injection
Lagooning/Cooling Ponds/Solar Evaporation Ponds
Centrifugation
Cooling Towers

Manpower requirements for each of these processes have been subdivided into the basic categories of operations, preventive maintenance, and corrective maintenance. In so doing, it is anticipated that all of the critical manpower requirements will have been identified for each process. To identify the qualitative requirements for a specific treatment system, it is only necessary to sum the requirements of the treatment processes involved. Naturally, the total requirements for a treatment system will also involve the incorporation of administrative and technical support requirements.

In determining personnel requirements, the following assumptions were made with respect to manpower in the chemical industries:

1. Waste treatment plant operators will perform routine preventive maintenance tasks in addition to their primary mission of operating and controlling unit treatment equipment and appurtenances.
2. Professional and para-professional support in solving exceptional waste treatment problems will be provided either through in-plant resources or

through technical consultants hired on an as-needed basis. Operator personnel should be capable of recognizing the presence of problems, but they cannot be expected to handle research investigations to solve the problems.

3. Skilled craftsmen will perform all complex corrective maintenance tasks on unit treatment equipment and appurtenances. These craftsmen will be drawn from in-plant resources in most cases, although in some plants the repair and overhaul of equipment will be handled through maintenance contracts with equipment manufacturers or independent construction and maintenance firms.

4. Laboratory analysis requirements for the treatment of waste will be fulfilled through the use of laboratory personnel and facilities currently available in nearly all plants. Laboratory personnel will be responsible for conducting routine analytical tests, such as settleable solids, pH, oils, total dissolved solids, acidity, alkalinity, phenols, ammonia, cyanides, total sulfate, total chlorides, and COD. The operator(s) of the waste treatment facility will normally collect and label samples for analysis. Operator(s) may perform simple tests, but they will rely primarily upon automatic instrumentation (such as pH meters) and laboratory results for controlling the waste treatment facility.

The above assumptions are currently valid for the chemical industry, and it is felt that they will continue to be valid well into the future.

Personnel requirements for each treatment process are presented in two ways: a listing of the tasks necessary for operating and maintaining the treatment process, and a summary description of the occupational areas encompassed by the tasks. The summary description represents a broad look at the occupations involved in the operation and maintenance of waste treatment facilities, while the task enumeration is intended to relate the specific requirements for each occupational area.

Included as part of the task enumerations for each treatment process, as shown in Appendix D, are several columns indicating the occupational area to which the task is related and the skill level judged appropriate to the task. There is also a column to indicate the frequency with which the task would be performed under average conditions. Task frequency is intended for general guidance purposes only; quantitative aspects of manpower requirements are covered in Chapter XIII.

It should be noted that for the corrective maintenance function within each treatment process, no frequency data are presented. Quantitative measures for this function are presently unavailable; many of the processes have never been fully exploited for waste treatment other than on a pilot basis, and meaningful data concerning frequency of task repetition have typically been neglected by industry. The frequency for corrective maintenance tasks is also subject to great fluctuation due to equipment age and the environmental factors to which equipment is exposed.

Skill levels for the tasks are defined on a numerical scale of three discrete levels. Skill level numbers are provided for the purpose of illustrating the relative difficulty of the tasks as they relate to effective waste treatment and, consequently, the skill and knowledge requirements for the individual who has responsibility for performing the tasks. The three skill levels are defined as:

Skill Level 1	Relatively simple task which does not require extensive training or experience. A high degree of proficiency can generally be acquired without a great deal of practice where there are no stringent demands for speed or accuracy and no requirements for drawing conclusions or making decisions. Being shown or told how to perform the task is usually sufficient training.
Skill Level 2	Relatively complex task which requires formal training on the procedures, operating principles, and theory involved. At least some on-the-job training and experience are required to gain specific equipment knowledge and proficiency, facts and principles must be analyzed and conclusions drawn, and relatively routine decisions must be made in order to preserve effective waste treatment. There are some demands for speed and accuracy.

Skill Level 3	Highly complex task which requires formal training and a great deal of experience. Nomenclature, procedures, operating principles, and complete theory must be mastered for effective completion of the task. Facts and principles must be analyzed and evaluated in order to reach proper decisions, speed and accuracy requirements are quite stringent, and non-routine situations must be dealt with. Failure in performing the task will yield ineffective waste treatment and may result in great expense for damage or repairs.

The skill level indications can be most effectively used after consolidating treatment process requirements according to a particular system. The skill levels will then provide a dimension for ascertaining appropriate quantitative proportions of personnel by skill level. Greater attention is focused on this in the next chapter.

It will be necessary for the user of the qualitative manpower requirements to make certain deductions in order to put the information into the context of a specific treatment system application. In operating and maintaining pumps, for example, the user must deduce that the tasks listed will be performed on the particular type of pump best suited to the liquids and volume, pressure, and head requirements of this system. Tasks inappropriate to that specific pump would be deleted, e.g., if only centrifugal pumps would be used, those tasks for reciprocating and diaphragm pumps would be unnecessary as personnel requirements.

Descriptions of Personnel

The following descriptions are provided as a brief consolidation of the qualitative manpower requirements for waste treatment in the chemical industries. It should be noted that there is not currently a Dictionary of Occupational Titles (DOT) listing to accurately describe the job responsibility of operations personnel in the treatment of chemical industry waste. The titles of waste treatment plant operator (inorganic wastes), waste treatment plant attendant (inorganic wastes), and waste treatment plant worker (inorganic wastes), are suggested on an interim basis and are not to be found in the DOT. It is felt that standard listings adequately describe qualitative requirements in other functional areas of waste treatment; their inclusion here is for completeness.

To determine the specific tasks included within each of the job classifications, refer to Appendix D, Qualitative Personnel Requirements for Treatment Processes.

Abbreviations found in the Appendix are defined as:

OP	Waste Treatment Plant Operator
Ins Repmn	Instrument Repairman
Mech Main	Maintenance Mechanic
Lab Test	Laboratory Technician
Pump Serv	Water Pump Serviceman
Pipe Ftr	Pipe Fitter, Maintenance
Elec	Electrician, Maintenance

Waste Treatment Plant Operator (Inorganic Waste)
Suggested Occupational Classification Code: 955.120

Operates water treatment plant to remove thermal and inorganic contamination from industrial wastewaters. Monitors instrumentation panels and adjusts valves and gates manually or by remote control to regulate the processing and disposal of wastewater. Operates and maintains chemical addition, oil removal, sedimentation, filtration, reverse osmosis, electrodialysis, ion exchange, multiple effect evaporation, deep well injection, centrifugation, and cooling tower treatment processes. Gives directions and on-the-job training to waste treatment plant technicians and waste treatment plant assistants in operating and maintaining water treatment equipment. Interprets instrumentation readings and water test results, compiles various operating records, and may perform tests for pH, alkalinity, suspended solids, and total dissolved solids.

Qualifications Profile:

GED:[1] Applies principles of waste treatment systems to solve a variety of practical problems and deal with concrete variables in situations where only limited standardization exists. Interprets a variety of instructions furnished in written, oral, diagrammatic, or schedule form. Performs ordinary arithmetic, algebraic, and geometric procedures in standard, practical applications. Comprehension and expression ability appropriate to the interpretation of technical manuals as well as drawings and specifications such as layouts, blueprints, and schematics.

SVP:[2] Over one year and up to two years of vocational training, special short course training, and essential experience on-the-job. Technical skills and knowledge must be acquired in all phases of the waste treatment system for which the Waste Treatment Plant Operator will assume responsibility.

APTITUDE:

Intelligence - Middle third of the population, ranging from slightly below to slightly above average.

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[1] General Educational Development embraces those aspects of education (formal and informal) which contribute to the worker's (a) reasoning development and ability to follow instructions, and (b) acquisition of "tool" knowledges, such as language and mathematical skills. It is education of a general nature which does not have a recognized, fairly specific, occupational objective. Ordinarily, such education is obtained in elementary school, high school, or college. It also derives from experience and individual study.

Verbal - Middle third of the population, ranging from slightly below to slightly above average.

Numerical - Middle third of the population, ranging from slightly below to slightly above average.

Spatial - Middle third of the population, ranging from slightly below to slightly above average.

Form Perception - Middle third of the population, ranging from slightly below to slightly above average.

Clerical Perception - Lowest third of the population, excluding the bottom 10 percent of the population.

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[2] Specific Vocational Preparation refers to the time required to learn the techniques, acquire information, and develop the facility needed for average performance in a specific job-worker situation. This training may be acquired in a school, work, military, institutional, or avocational environment. It does not include orientation training required of even fully qualified workers to become accustomed to the special conditions of any new job. Specific vocational training includes training given in any of the following circumstances:

a. Vocational education (such as high school shop training, technical school, and that part of college training which is organized around a specific vocational objective);
b. Apprentice training;
c. In-plant training (given by an employer in the form of organized classroom study);
d. On-the-job training (serving as trainee on the job under the instruction of a qualified worker);
e. Essential experience on other jobs (serving in less responsible jobs which lead to the higher grade job or serving in other jobs which qualify).

Motor Coordination - Middle third of the population, ranging from slightly below to slightly above average.

Finger Dexterity - Middle third of the population, ranging from slightly below to slightly above average.

Manual Dexterity - Middle third of the population, ranging from slightly below to slightly above average.

Eye-Hand-Foot Coordination - Lowest third of the population, excluding the bottom 10 percent.

Color Discrimination - Middle third of the population, ranging from slightly below to slightly above average.

INTERESTS: Preference for activities dealing with:
- things and objects;
- situations of a scientific or technical nature; and
- situations of a routine, concrete, organized nature.

TEMPERAMENTS: Worker must adjust to:
- situations involving the evaluation of information against measurable or verifiable criteria; and
- situations involving the precise attainment of set limits, tolerances, or standards.

PHYSICAL DEMANDS:
Light and medium work primarily limited to reaching, handling, and feeling and visual functions of acuity, near and far, and color vision.

WORKING CONDITIONS:
The worker must adapt to working both inside and outside, situations in which he will be exposed to the definite risk of bodily injury, and situations in which he will be exposed to toxic dust, fumes, gases, vapors, mists, or liquids

which can cause localized disabling as a result of inhalation or action on the skin.

Related DOT Classifications:

Waste Treatment Operator (chem.)	DOT 559.782
Senior Sewage-Plant Operator (san. ser.)	DOT 955.130

Waste Treatment Plant Attendant (Inorganic Waste)
Suggested Occupational Classification Code: 955.462

Tends pumps, liquid and dry chemical feeders, blowers, sedimentation tanks, reverse osmosis units, electrodialysis units, ion exchange units, and other equipment used to decontaminate inorganic industrial wastewaters. Adjusts valves and gates manually or by remote control to regulate the flow and pressure of feedwater to treatment processing equipment; reads and interprets charts, flow meters, and other gages to determine operating efficiency of equipment; cleans, lubricates, and performs other preventive maintenance on water treatment equipment and appurtenances. Extracts samples, prepares process logs, and records meter and gage readings. Assists and gives directions to waste treatment plant assistants in performing routine operations as directed by the waste treatment plant operator.

Qualifications Profile:

GED:	Applies common sense in carrying out instructions furnished in written, oral, or diagrammatic form. Deals with problems involving several concrete variables in or from standardized situations. Makes arithmetic calculations involving fractions, decimals, and percentages. Comprehension and expression ability must be appropriate for the posting of data in logs and on special report forms and records.
SVP:	Over six months up to and including one year of vocational training, special short course training, and essential on-the-job experience. Technical skills and knowledge must be acquired in each of the treatment

processes for which the Waste Treatment Plant Attendant will assume responsibility.

APTITUDE:

Intelligence - Middle third of the population, ranging from slightly below to slightly above average.

Verbal - Middle third of the population, ranging from slightly below to slightly above average.

Numerical - Middle third of the population, ranging from slightly below to slightly above average.

Spatial - Middle third of the population, ranging from slightly below to slightly above average.

Form Perception - Middle third of the population, ranging from slightly below to slightly above average.

Clerical Perception - Lowest third of the population, excluding the bottom 10 percent of the population.

Motor Coordination - Middle third of the population, ranging from slightly below to slightly above average.

Finger Dexterity - Middle third of the population, ranging from slightly below to slightly above average.

Manual Dexterity - Middle third of the population, ranging from slightly below to slightly above average.

Eye-Hand-Foot Coordination - Lowest third of the population, excluding the bottom 10 percent.

Color Discrimination - Middle third of the population, ranging from slightly below to slightly above average.

INTERESTS: Preference for activities dealing with:
- things and objects;
- situations of a scientific or technical nature; and
- situations of a routine, concrete, organized nature.

TEMPERAMENTS: Worker must adjust to:
- situations involving the evaluation of information against measurable or verifiable criteria; and
- situations involving the precise attainment of set limits, tolerances, or standards.

PHYSICAL DEMANDS:

Light and medium work primarily limited to reaching, handling, and feeling and visual functions of acuity, near and far, and color vision.

WORKING CONDITIONS:

The worker must adapt to working both inside and outside, situations in which he will be exposed to the definite risk of bodily injury, and situations in which he will be exposed to toxic dust, fumes, gases, vapors, mists, or liquids which can cause localized disabling as a result of inhalation or action on the skin.

Related DOT Classifications:

Waste Treatment Operator (chem.)	DOT 559.782
Sewage Plant Attendant (san. ser.)	DOT 955.885
Water Treatment Plant Mechanic (water works)	DOT 630.281
Sewage Plant Operator	DOT 954.782

Waste Treatment Plant Worker (Inorganic Waste)
Suggested Occupational Classification Code: 955.787

Performs any combination of the following tasks in a waste treatment plant to assist in the removal of inorganic contaminants from industrial wastewater:

Cleans and refills chemical tanks and hoppers, cleans filter screens using brushes and hose, and opens or closes manually or remotely controlled valves or gates according to warning lights, gage readings, and the directions of waste treatment plant operator or waste treatment plant technician. Scrapes and scrubs processing tanks and equipment using chemicals and detergents, loads and removes grit and sediment from tanks, sumps, and catch basins using hand pumps, hoses, skinner hoes, shovels, and pails. Cleans and paints process equipment and appurtenances, lubricates pumps, valves and other equipment using grease guns and oil cans, and checks for leaks or other faults with process equipment.

Qualifications Profile:

GED: Applies common sense understanding to carry out simple one or two step instructions. Deals with standardized situations with occasional or no variables in or from these situations encountered on the job. Performs simple addition and subtraction, reading or copying of figures, or counting and recording. Comprehension and expression ability must be appropriate to the learning of job duties from oral instructions or demonstration and requesting orally, or in writing, such supplies and necessities as may be required on the job.

SVP: Anything beyond short demonstration up to and including 30 days of vocational training, special short course training, and on-the-job experience. Extensive skill and knowledge of the waste treatment plant operations are not pre-requisite to the work.

APTITUDE:

Intelligence - Lowest third of the population, excluding the bottom 10 percent.

Verbal - Lowest third of the population, excluding the bottom 10 percent.

Numerical - Lowest third of the population, excluding the bottom 10 percent.

Spatial - Lowest third of the population, excluding the bottom 10 percent.

Form Perception - Lowest third of the population, excluding the bottom 10 percent.

Clerical Perception - Lowest third of the population, excluding the bottom 10 percent.

Motor Coordination - Lowest third of the population, excluding the bottom 10 percent.

Finger Dexterity - Middle third of the population, ranging from slightly below to slightly above average.

Manual Dexterity - Middle third of the population, ranging from slightly below to slightly above average.

Eye-Hand-Foot Coordination - Lowest third of the population, ranging from slightly below to slightly above average.

Color Discrimination - Middle third of the population, ranging from slightly below to slightly above average.

INTERESTS: Preference for dealing with:
- things and objects;
- situations of a routine, concrete, organized nature; and
- situations that are non-social in nature, and are carried out in relation to processes, machines, and techniques.

TEMPERAMENTS: Worker must adjust to:
- situations involving repetitive or short cycle operations carried out according to set procedures or sequences; and
- situations involving doing things only under specific instructions, allowing little or no room for independent action in working out job problems.

PHYSICAL DEMANDS:

Medium and heavy work centered around lifting, carrying, stooping, reaching, and handling.

WORKING CONDITIONS:

The worker must adapt to working both inside and outside, situations in which he will be exposed to the definite risk of bodily injury, and situations in which he will be exposed to toxic dust, fumes, gases, vapors, mists, or liquids which can cause localized disabling as a result of inhalation or action on the skin.

Related DOT Classifications:

Sewage Disposal Worker (san. ser)	DOT 955.887
Sewage Plant Operator	DOT 954.782

Instrument Repairman (Any Ind.) DOT 710.281

Installs, repairs, maintains, and adjusts indicating, recording, telemetering, and controlling instruments used to measure and control variables such as pressure, flow, temperature, motion, force, and chemical composition, using hand tools and precision instruments. Disassembles malfunctioning instruments, and examines and tests mechanism and circuitry for defects. Troubleshoots equipment in or out of control system and replaces or repairs defective parts. Reassembles instrument and tests assembly for conformance with specifications, using instruments such as potentiometer, resistance bridge, manometer, and pressure gage. Inspects instruments periodically and makes minor calibration adjustments to assure functioning within specified standards. May adjust and repair final control mechanisms such as automatically controlled valves or positioners. May be designated according to type of instrument repaired as meter serviceman; panel-instrument repairman, pneumatic control equipment repairman.

Carpenter, Maintenance (Any Ind.) DOT 860.281

Carpenter, repair; carpentry repairman. Constructs and repairs structural woodwork and equipment in an establishment, working from blueprints, drawings, or oral instructions: Builds, repairs, and installs counters, cabinets, benches, partitions, floors, doors, building framework, and trim, using carpenter's handtools and power tools. Installs glass in windows, doors, and partitions. Replaces damaged ceiling tile, floor tile, and sheet plastic wall coverings. May build cabinets and other wooden equipment in carpenter shop, using woodworking machines, such as circular saw, bandsaw, and jointer.

Maintenance Mechanic (Any Ind.) II DOT 638.281

Repairs and maintains, in accordance with diagrams, sketches, operation manuals, and manufacturer's specifications, machinery and mechanical equipment, such as cranes, pumps, engines, motors, pneumatic tools, conveyor systems, production machines, and automotive and construction equipment, using handtools, power tools, and precision-measuring and testing instruments: Observes mechanical devices in operation and listens to their sounds to locate causes of trouble. Dismantles devices to gain access to and remove defective parts, using hoists, cranes, handtools, and power tools. Examines form and texture of parts to detect imperfections. Inspects used parts to determine changes in dimensional requirements, using rules, calipers, micrometers, and other measuring instruments. Adjusts functional parts of devices and control instruments, using handtools, levels, plumb bobs, and straightedges. Repairs or replaces defective parts, using handtools and power tools. Installs special functional and structural parts in devices, using handtools. Starts devices to test their performances. Lubricates and cleans parts. May set up and operate lathe, drill press, grinder, and other metalworking tools to make and repair parts. May initiate purchase order for parts and machines. May repair electrical equipment.

Laboratory Technician (Any Ind.) DOT 029.181

Performs laboratory tests according to prescribed standards to determine chemical and physical characteristics or composition of solid, liquid, or gaseous materials and substances for purposes such as quality control, process control, product development, or determining conformity to specifications: Sets up and adjusts laboratory apparatus, and operates grinders, agitators, centrifuges, ovens, condensers, and vibrating screens to prepare material for testing according to established laboratory procedure. Performs physical tests on samples of cement or raw materials and controls quality of materials and mix during manufacturing process. Tests raw materials, such as aggregate, limestone, and sand, for such qualities as permeability, load-bearing capacity, or cohesiveness. Tests dry and liquid substances used as ingredients in adhesives, propellants, lubricants, refractories, synthetic rubber, paint, paper, and other compounds for purity, viscosity, density, absorption or burning rate, melting point, or flash point, using viscosimeter, torsion balance scale, and pH meter. Tests solutions used in processes, such as anodizing, water-proofing, cleaning, bleaching, and pickling, for chemical strength, specific gravity, or other specifications. Tests materials for presence and content of elements or substances, such as hydrocarbons, manganese, natural grease or impurities, tungsten, sulfur, cyanide, ash, or dust. Tests samples of manufactured products, such as cellophane or glassware, to verify conformity with heat resistance, tensile strength, ductility, and other specifications. Examines materials, using microscope. Records test results on standard forms, writes test reports describing procedures used, and prepares graphs and charts. Cleans and sterilizes laboratory apparatus. May prepare chemical solutions according to standard formulas. May add chemicals or raw materials to process solutions or product batches to correct deviations from specifications.

Water Pump Serviceman (Any Ind.) DOT 630.281

Repairs pumps and pump power units, such as centrifugal and plunger-type pumps, and diesel-engine, gasoline-engine, and electric-motor power units, using hoists and mechanics' and electricians' handtools. Diagnoses trouble in pumps. Dismantles pumps and repairs or replaces defective parts, using handtools. Reseats and grinds valves. Tests performances of repaired pumps. May wire motor to switchboard and install fuse box. May be designated according to type of pump repaired as Water Pump Serviceman.

Pipe Fitter, Maintenance (Any Ind.) DOT 862.381

Determines defects in and maintains piping systems for steam, gas, water, air, acid, and paints in industrial or commercial establishments: Inspects system to ascertain cause of malfunction. Reads blueprint or schematic drawings to determine work aids and procedures, using knowledge of high and low pressure systems, plumbing, and pressure capacities of piping materials. Measures, cuts, threads, and installs pipes, valves, gages, and other fixtures, using handtools, pipe cutter, pipe-threading machine, and pipe-bending machine. Paints and insulates pipe and fittings. May repair, clean, and adjust control devices, such as thermal and magnetic switches and relays. May maintain and repair auxiliary equipment, such as pumps and motors.

Electrician, Maintenance (Any Ind.) DOT 829.281

Repairs, maintains, and installs electrical systems and equipment, such as motors, transformers, wiring, switches, and alarm systems: Locates and determines electrical malfunction, using test instruments, such as ammeter, oscilloscope, and test lamp. Repairs malfunction by such methods as replacing burnt-out elements and fuses, bypassing or replacing defective wiring, filing switch contact points, and cleaning or rewiring motors, using handtools. Tests electrical equipment, such as generators and heaters for safety and efficiency, using standard test equipment, and by observing functioning. Installs fixtures, motors, and other electrical equipment. Makes equipment adjustment, using handtools. Inspects circuits and wiring for specified shielding and grounding and repairs or rewires system according to building codes and safety regulations. May replace bearings in electric motors. May repair mechanical, pneumatic, hydraulic, or electronic components of electrical equipment, using standard tools, gages, and procedures. May plan layout and wire new installations (Electrician). May be required to hold license. May be designated according to equipment repaired as Electrician, Crane Maintenance; Time Clock Repairman (elec. equip.); or according to work location as Electrician, Machine Shop (mach. shop); Electrician, Refinery (petrol. refin.).

CHAPTER XIII

QUANTITATIVE MANPOWER REQUIREMENTS

General

The next decade will witness a tremendous growth in the investment of manpower necessary to improve and preserve this nation's water resources. The need for additional qualified manpower will result primarily from an increase in the volume of industrial waste effluent and an accelerated program to decrease the level of wastewater contamination. The latter factor, that of increasingly stringent requirements being placed upon waste effluent, is by far the more important of the two factors. This chapter concerns itself with projections of manpower requirements for effective waste treatment in the inorganic chemical industry from two basic views. First, manpower is projected through 1974 with respect to the degree of commitment felt necessary for achieving specified levels of effluent quality. These projections are designed to reflect units of time, either in man-hours per day or man-hours per year, for each occupational area defined in Chapter XII. The most important application of these data will be in determining the human resources necessary for operating a waste treatment system. Secondly, manpower is projected with respect to the number of persons who must be specially trained, or otherwise qualified, to ensure effective wastewater treatment. These projections are distinguished from the former in that they deal with whole numbers of people and are directed specifically toward specific skills and knowledge related to wastewater treatment. These projections are more useful for their training implications than for forecasting absolute labor requirements in wastewater treatment.

The method chosen for developing manpower projections centers around the unit treatments which comprise a waste treatment system. Despite wide variation between chemical plants, the nature of the waste, and the volume of waste produced, the configuration and operational aspects of individual wastewater treatment units remain essentially constant. It is felt that the development of manpower data for unit treatments will not only assist in formulating the manpower forecasts contained in this report, but will provide a prototype for future projections and for wastewater treatment manpower needs in other industries.

A major assumption in utilizing quantitative measures on a unit treatment basis is that the data developed for unit treatment processes will be effectively additive across processes within a system. If this is accepted (there has been no evidence shown for rejecting it), then manpower requirements for a total wastewater treatment system can be estimated by summing across the treatment processes involved in that system. While the technique shows real promise, there are insufficient data at the present time to fully verify the concept. To collect and organize statistically significant data through empirical observation was beyond the scope of the present effort. However, sufficient data were collected through field visits and survey forms to permit gross verification of the quantitative manpower measures. In addition, the measures were judged to be reasonably accurate through the subjective opinions of a panel of experts in the field of waste treatment.

Although there is a profound lack of wastewater treatment personnel data, there is a relative wealth of maintenance cost information for chemical process equipment. J. D. Leonard (1) conducted a rather comprehensive survey on this subject during the late 1940's and early 1950's. If one assumes that the maintenance requirements for waste treatment equipment are similar to those for process equipment, one can derive econometrically labor requirements from cost data. Given D. E. Pierce's (2) equation

$$C = X\ (a + by)$$

where c = cost, dollars per year
x = KWHR per year/1000
y = cost in dollars per man-hour with overhead
a = repair material in dollars/1000 KWHR
b = repair labor in man-hours/1000 KWHR

which states that maintenance cost is a function of use, materials, and labor, one may with some confidence utilize Leonard's cost data (in 1969 dollars). On further examination, it was soon realized that Pierce's equation must be revised since available data would not support all of the required variables. A more general equation was derived as follows. If the ratio of labor cost to material cost is known, one may show that

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(1) J. D. Leonard, What Does Maintenance Cost, Chem. Eng., 58(9): 149 (1951).

(2) D. E. Pierce, A Common Denominator for Repair Costs, Chem. Eng. Procr., 44: 252 (1948).

$$b = (R)\ (C)\ (S)\ /\ L$$

where
b = operating and maintenance labor in man-hours
R = ratio of labor costs to total operating and maintenance costs
C = operating and maintenance cost per year (1)
S = use of size factor
L = labor rate (3)

Many of the quantitative manpower measures in this report are the result of applying this equation to available data for treatment processes. R in each case was derived through professional judgment of a number of experts in the field of waste treatment.

Labor man-hours were distributed across the four functional areas of Operations, Maintenance, Technical Management and Services, and Administration and Support Services in the following manner. Based on professional judgment and historical documentation, it would seem reasonable to split total operating and maintenance time so that 85% of the total would be considered operations plus preventive maintenance, and the remaining 15% would be corrective maintenance. Assuming that "operator" personnel are responsible for operating treatment equipment and performing necessary preventive maintenance, and "maintenance" personnel perform only corrective maintenance, it becomes possible to allocate the calculated measure across the two functional areas. Further, assume that Operations and Maintenance functions combined represent only 80% of the total manpower requirements for a treatment system and the remaining 20% account for Technical Management Services, and Administrative and Support Services. Inspection of military and industrial manpower data suggests that these two functional areas represent about 12.8% and 7.2%, respectively, of the total manpower required for a typical organizational structure in a technical environment. With the value already generated for operating and maintenance labor, it is a simple matter to calculate a grand total for the treatment process and proportion labor time to Technical Management and Administrative functions. Having distributed time across the four functional areas, distribution of time within each functional area was based upon judgment of the proportional contributions of each personnel type to the treatment process. Each of the treatments applicable to manpower projections considered in this report was developed in this manner. For treatment processes not included as part of the manpower projections, but applicable to the inorganic chemical industry, limited data are provided in a less refined form.

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(1) J. D. Leonard, ibid

(3) Manufacturing Chemists Association, Inc., Chemical Statistics Handbook, Washington, D.C., MCA, 1966.

Manpower projections were developed for two levels of treatment, two sizes of plant, and for the years 1969 through 1974. Plants were categorized as large or small according to volume of wastewater flow. Projected industrial growth was expressed in terms of daily wastewater flow and number of large and small plants. Average flow for large and small plants and treatment levels are consolidated in the following table:

LARGE PLANTS:

Level I - 27% removal

	1969	1970	1971	1972	1973	1974
equalization	1.9 mgd	2.0	2.1	2.2	2.4	2.5
chemical addition	0.19 mgd	0.2	.21	.22	.24	.25
lagooning	1.9 mgd	2.0	2.1	2.2	2.4	2.5

Level II - 100% removal

	1969	1970	1971	1972	1973	1974
equalization	1.9 mgd	2.0	2.1	2.2	2.4	2.5
chemical addition	1.9 mgd	2.0	2.1	2.2	2.4	2.5
sedimentation	1.9 mgd	2.0	2.1	2.2	2.4	2.5
filtration	1.9 mgd	2.0	2.1	2.2	2.4	2.5
reverse osmosis	1.9 mgd	2.0	2.1	2.2	2.4	2.5
deep well	0.19 mgd	.20	.21	.22	.24	.25

SMALL PLANTS:

Level I - 27% removal*

	gpd 1969	1970	1971	1972	1973	1974
equalization	9,800	10,200	10,800	11,400	12,000	12,800
chemical addition	9,800	10,200	10,800	11,400	12,000	12,800
lagoon	9,800	10,200	10,800	11,400	12,000	12,800

*It has been assumed that ultimate disposal of effluents from small plants will be to municipal sewerage systems.

Quantitative Personnel Requirements for Treatment Processes

Quantitative personnel requirements on a treatment process and waste volume basis are presented in the following paragraphs. Operation and maintenance labor as a function of use or size factor is included for reference purposes. Labor values generated by this function are presented in tabular form according to the proportional distributions discussed earlier. It should be noted that the distribution of labor among specific personnel types varies among treatment processes. Inspection of the qualitative data, along with subjective rationalization of the ratios of personnel appropriate to the tasks involved, resulted in tailored allocations for each treatment process.

Equalization

The primary components of an equalization treatment process are pumps and tanks. The manpower estimates for this treatment were derived by summing man-hour requirements for the two components.

Using an R factor of 0.9 for centrifugal pumps, operations and maintenance labor for pumps was computed to be:

26.5 man-hrs/year for 30 gpm, 50 ft. head
36.0 man-hrs/year for 100 gpm, 50 ft. head
90.0 man-hrs/year for 2,000 gpm, 50 ft. head

Labor associated with operation and maintenance of concrete, stainless steel, or aluminum tanks was computed using the formula, which was reduced to the simple function

man-hrs/year = 1.42 N, where N is tank capacity in gal./1000

Labor for tanks was computed to be:

1.4 man-hrs/year for 1000 gal tank
11.3 man-hrs/year for 8000 gal tank
113 man-hrs/year for 80,000 gal tank

Combining the two yielded the following operations and maintenance labor for equalization:

8,000 gpd to 13,000 gpd = 28 man-hrs/year
0.19 mgd to 0.25 mgd = 47 man-hrs/year
1.9 mgd to 2.5 mgd = 203 man-hrs/year

Table I indicates how this labor was distributed across personnel for the various volumes of flow.

Chemical Addition

Operating and maintenance labor requirements for chemical addition treatment were derived by extrapolating data for limestone neutralization of acid mine drainage (4). The data are based on an acid content of 2,000 ppm to be neutralized.

9,800 gpd = 650 man-hrs/year
10,200 = 700
10,800 = 740
11,400 = 760
12,000 = 780
12,800 = 800

0.19 mgd = 1750 man-hrs/year
0.20 = 1900
0.21 = 2100
0.22 = 2250
0.24 = 2400
0.25 = 2500

1.9 mgd = 4860 man-hrs/year
2.0 = 5020
2.1 = 5600
2.2 = 5900
2.4 = 6000
2.5 = 6100

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(4) Engineering Economic Study of Mine Drainage Control Techniques. Appendix B to Acid Mine Drainage in Appalachia, A report by the Appalachian Regional Commission. Cyrus Wm. Rice and Company, Pittsburgh, Pa., 1969

TABLE I

EQUALIZATION
MAN-HOURS/YEAR

1.9 mgd	8,000-13,000 gpa	
		Operation
17	2	Waste Treatment Plant Operator
51	7	Waste Treatment Plant Attendant
103	13	Waste Treatment Plant Worker
		Maintenance
6	1	Instrument Repairman
15	2	Water Pump Serviceman
		Maintenance Mechanic
3	1	Pipe Fitter, Maintenance
6	1	Electrician, Maintenance
		Other Maintenance
		Technical Management & Services
22	3	Laboratory Technician
10	1	Technical Management & Services
		Administrative & Support
18	3	Administrative & Support Services

The following Table II indicates how this labor was distributed across personnel for the various volumes of flow.

Lagooning

Operations and maintenance labor for lagoons was obtained by summing the labor requirements for pumps with an estimate of labor required for cleaning a lagoon on a periodic basis. Labor for the cleaning operation was determined by calculating the settleable solids likely to be deposited as a function of waste volume and solids content of the effluent.

Assuming a settleable solids content of 500 ppm, the following estimates were made for removing settled solids on a yearly basis:

9,800 gpd to 12,800 gpd = 7.5 cu.yd./yr = <1 man-hr/yr

(Based on man-hours/year of heavy equipment operator time, assuming that with the proper equipment [such as high lift] solids can be removed at the rate of 35 tons per hour.)

1.9 mgd = 1295 cu.yd/year = 37 man-hours/year
2.0 = 1344 = 38
2.1 = 1436 = 41
2.2 = 1484 = 42.4
2.4 = 1619 = 46.3
2.5 = 1686 = 48.2

Adding 26.5 man-hours per year for a 30 gpm, 50 foot head centrifugal pump (for 9,800 - 12,000 gpd volume) and 90.0 man-hours per year for a 2,000 gpm, 50 foot head centrifugal pump (for 1.9-2.5 mgd volume) yields the following operations and maintenance labor for lagoons:

9,800 to 12,800 gpd = 27 man-hours/year

1.9 mgd = 127 man-hrs/year
2.0 = 128
2.1 = 131
2.2 = 132
2.4 = 136
2.5 = 138

The following Table III indicates how this labor was distributed across personnel for the various volumes of flow. It should be noted that corrective maintenance for this treatment was assumed to be 85%, and preventive maintenance and operations represent the remainder. Operational aspects of lagooning are minimal.

TABLE II

CHEMICAL ADDITION
MAN-HOURS/YEAR

	Operation			Maintenance						Technical Management & Services		Adm. & Support
	Waste Treat. Plant Operator	Waste Treat. Plant Attendant	Waste Treat. Plant Worker	Instrument Repairman	Water Pump Serviceman	Maint. Mechanic	Pipe Fitter Maint.	Elect. Maint.	Other Maint.	Lab. Tech.	Tech. Mgt. & Serv.	Adm. & Support Serv.
2.5	037	074	2074	183	183	183	183	183		488	488	549
2.4	1020	2040	2040	180	180	180	180	180		480	480	540
2.2	1003	2006	2006	177	177	177	177	177		472	472	531
2.1	952	1904	1904	168	168	168	168	168		448	448	504
2.0	853	1707	1707	151	151	151	151	151		402	402	451
1.9 mgd	826	1652	1652	146	146	146	146	146		389	389	437
0.25	425	850	850	75	75	75	75	75		200	200	225
0.24	408	816	816	72	72	72	72	72		192	192	216
0.22	382	765	68	68	68	68	68	68		180	180	202
0.21	357	714	714	63	63	63	63	63		168	168	189
0.20	323	646	646	57	57	57	57	57		152	152	171
0.19mgd	298	595	595	53	53	53	53	53		140	140	158
12,800	136	272	272	24	24	24	24	24		64	64	72
12,000	133	265	265	23	23	23	23	23		63	63	70
11,400	129	258	258	23	23	23	23	23		61	61	68
10,800	126	252	252	22	22	22	22	22		59	59	67
10,200	119	238	238	21	21	21	21	21		56	56	63
9,800gpd	111	221	221	20	20	20	20	20		52	52	59

TABLE III

LAGOONING
MAN-HOURS/YEAR

2.5 mgd	2.4 mgd	2.2 mgd	2.1 mgd	2.0 mgd	1.9 mgd	9,800-12,800 gpd	
							Operation
4	4	4	4	4	4	1	Waste Treatment Plant Operator
25	25	24	23	23	23	5	Waste Treatment Plant Attendant
12	12	12	12	11	11	2	Waste Treatment Plant Worker
							Maintenance
							Instrument Repairman
19	19	18	18	18	13	4	Water Pump Serviceman
19	19	18	18	18	18	4	Maintenance Mechanic
10	10	9	9	9	9	2	Pipe Fitter, Maintenance
							Electrician, Maintenance
49	48	46	46	45	45	10	Other Maintenance 1/
							Technical Management & Services
18	18	17	17	16	16	3	Laboratory Technician
4	4	4	4	4	4	1	Technical Management & Services
							Administrative & Support
12	12	12	12	12	11	2	Administrative & Support Services

1/ Heavy Equipment Operator

Sedimentation

Operating and maintenance labor for the sedimentation treatment was developed using the general formula, which was reduced to

man-hours/year = 169.8 V

where V is tank volume in gal./2,000. The following data were generated for clarifiers on the basis of handling 62 gallons per day per cubic foot of volume:

1.9 mgd = 1936 man-hrs/year
2.0 = 2053
2.1 = 2157
2.2 = 2258
2.4 = 2464
2.5 = 2567

The following Table IV indicates how this labor was distributed across personnel for the various volumes of flow.

Filtration

Operating and maintenance labor for filtration was based on the utilization of a rotary vacuum filtration unit. The general formula was reduced to

man-hours/year = .70 S

where S is the surface area of the filter in square feet.

Assuming suspended solids of 500 ppm and a filter capability of eight pounds per day per square foot, the following was developed:

1.9 mgd = 623 man-hours/year
2.0 = 654
2.1 = 688
2.2 = 721
2.4 = 787
2.5 = 820

The following Table V shows the distribution of this labor across personnel for the various volumes of waste flow.

TABLE IV

SEDIMENTATION
MAN-HOURS/YEAR

2.5 mgd	2.4 mgd	2.2 mgd	2.1 mgd	2.0 mgd	1.9 mgd	
						Operation
436	418	384	367	349	329	Waste Treatment Plant Operator
655	628	576	550	524	494	Treatment Plant Attendant
1091	1047	960	917	873	823	Waste Treatment Plant Worker
						Maintenance
77	74	68	65	62	58	Instrument Repairman
77	74	68	65	62	58	Water Pump Serviceman
77	74	68	65	62	58	Maintenance Mechanic
77	74	68	65	62	58	Pipe Fitter, Maintenance
		68	65	62	58	Electrician, Maintenance
						Other Maintenance
						Technical Management & Services
206	197	181	173	164	155	Laboratory Technician
206	197	181	173	164	155	Technical Management & Services
						Administrative & Support
231	222	203	194	185	174	Administrative & Support Services

TABLE V

FILTRATION
MAN-HOURS/YEAR

2.5 mgd	2.4 mgd	2.2 mgd	2.1 mgd	2.0 mgd	1.9 mgd	
						Operation
139	134	122	117	116	106	Waste Treatment Plant Operator
209	201	184	176	167	159	Waste Treatment Plant Attendant
349	335	306	293	278	265	Waste Treatment Plant Worker
						Maintenance
25	24	22	21	20	19	Instrument Repairman
25	24	22	21	20	19	Water Pump Serviceman
25	24	22	21	20	19	Maintenance Mechanic
25	24	22	21	20	19	Pipe Fitter, Maintenance
25	24	22	21	20	19	Electrician, Maintenance
						Other Maintenance
						Technical Management & Services
66	63	58	55	53	51	Laboratory Technician
66	63	58	55	53	51	Technical Management & Services
						Administrative & Support
74	71	65	62	59	58	Administrative & Support Services

Reverse Osmosis

Operating and maintenance labor for this treatment process was developed through the extrapolation of data for reverse osmosis treatment of acid mine drainage (4). The figures extrapolated were based on 1.67 mgd feedwater with total dissolved solids of 500 ppm and total acidity of 1667 ppm.

	Corrective Maintenance	Preventive Maintenance and Operations	Total Operating and Maintenance Labor
1.9 mgd	1750 man-hrs/yr	3750 man-hrs/yr	5500 man-hrs/yr
2.0	1800	3800	5600
2.1	1850	3850	5700
2.2	1900	3900	5800
2.4	1950	3950	5900
2.5	2000	4000	6000

The following Table VI indicates how this labor was distributed across personnel for the various volumes of flow. It should be noted that corrective maintenance for reverse osmosis represents one-third of total labor; for most other treatment processes corrective maintenance represents about 15% of the combined labor.

Deep Well Injection

Operations and maintenance labor for deep well injection was derived through the general formula, which was reduced to

$$\text{man-hours/year} = .00066\ G$$

where G is gallons per day. Labor for deep well was computed to be:

0.19 mgd = 125 man-hours/year
0.20 = 132
0.21 = 139
0.22 = 145
0.24 = 159
0.25 = 165

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(4) Cyrus Wm. Rice and Company, 1969, ibid

TABLE VI

REVERSE OSMOSIS
MAN-HOURS/YEAR

2.5 mgd	2.4 mgd	2.2 mgd	2.1 mgd	2.0 mgd	1.9 mgd	
						Operation
1600	1580	1560	1540	1520	1500	Waste Treatment Plant Operator
1600	1580	1560	1540	1520	1500	Waste Treatment Plant Attendant
800	790	780	770	760	750	Waste Treatment Plant Worker
						Maintenance
200	195	190	185	180	175	Instrument Repairman
800	780	760	740	720	700	Water Pump Serviceman
600	585	570	555	540	525	Maintenance Mechanic
200	195	190	185	180	175	Pipe Fitter, Maintenance
200	195	190	185	180	175	Electrician, Maintenance
						Other Maintenance
						Technical Management & Services
384	378	371	365	358	352	Laboratory Technician
576	566	557	547	538	528	Technical Management & Services
						Administrative & Support
540	531	522	513	504	495	Administrative & Support Services

The following Table VII indicates how this labor was distributed across personnel for the various volumes of throughput.

Projected Manpower Requirements

Manpower requirements for the inorganic chemical industry were compiled by summing the requirements for individual treatment processes. The manpower requirements are expressed in man-hours per year for all categories of personnel. In addition, the three operator classifications are expressed in man-hours per day, based on 365-day operation of the waste treatment facility. For many of the personnel it should be assumed that a requirement will not exist on a day-to-day basis, but rather that a requirement will occur sporadically in much larger units of time. For example, maintenance personnel will generally contribute a large block of time in a single unit and then not be called upon again for some time. For maintenance personnel, as well as administrative and technical support personnel, man-hours per year is more meaningful than man-hours per day.

Tables VIII through XII summarize manpower requirements on a treatment level basis for the years 1969 through 1974.

To simplify compilation of the total number of people involved in waste treatment operations, and because there is no reliable way to predict exactly how a plant will choose to delegate specific personnel types, the manpower data for all three operations classifications have been combined to reflect total operator manpower on a daily basis. The figures included for each personnel class will serve to identify the proportional division appropriate for the three classifications of operator.

Number of Qualified Operators Required

It is the concensus of wastewater treatment experts that there should always be a qualified individual on hand during the operation of a waste treatment facility to monitor and verify the effectiveness of waste treatment. In order to provide such coverage, it will be necessary to train and qualify more people than would normally be required to actually operate and maintain the treatment system. The backup capability has been neglected in past years, and continued neglect will almost certainly result in less-than-effective wastewater treatment in the future. It has been quite common, particularly in industries operating continuously or on multiple shifts, to have problems

TABLE VII

DEEP WELL INJECTION
MAN-HOURS/YEAR

0.25 mgd	0.24 mgd	0.22 mgd	0.21 mgd	0.2 mgd	0.19 mgd	
						Operation
42	41	37	35	34	32	Waste Treatment Plant Operator
70	68	62	59	56	53	Waste Treatment Plant Attendant
28	27	25	24	22	21	Waste Treatment Plant Worker
						Maintenance
3	2	2	2	2	2	Instrument Repairman
10	10	9	8	8	8	Water Pump Serviceman
8	7	7	6	6	6	Maintenance Mechanic
3	2	2	2	2	2	Pipe Fitter, Maintenance
3	2	2	2	2	2	Electrician, Maintenance
						Other Maintenance
						Technical Management & Services
10	10	9	9	8	8	Laboratory Technician
16	15	14	13	13	12	Technical Management & Services
						Administrative & Support
15	14	13	13	12	11	Administrative & Support Services

TABLE VIII

LARGE PLANT
LEVEL I TREATMENT-27% REMOVAL
EQUALIZATION, CHEMICAL ADDITION, LAGOON

1969	1970	1971	1972	1973	1974		
							Operation
319	344	378	403	429	446	Man-Hrs/Yr.	Waste Treatment Plant Operator
.87	.94	1.04	1.10	1.18	1.22	Man-Hrs/Day	
669	720	788	840	892	926	Man-Hrs/Yr.	Waste Treatment Plant Attendant
1.83	1.97	2.16	2.30	2.44	2.54	Man-Hrs/Day	
709	760	829	880	931	965	Man-Hrs/Yr.	Waste Treatment Plant Worker
1.94	2.08	2.27	2.41	2.55	2.64	Man-Hrs/Day	
							Maintenance
59	63	69	74	78	81	Man-Hrs/Yr.	Instrument Repairman
86	90	96	101	106	109	"	Water Pump Serviceman
71	75	81	86	91	94	"	Maintenance Mechanic
65	69	75	80	85	88	"	Pipe Fitter, Maintenance
59	63	69	74	78	81	"	Electrician, Maintenance
45	45	46	46	48	49	"	Other Maintenance
							Technical Management & Services
178	190	207	219	232	240	"	Laboratory Technician
154	166	182	194	206	214	"	Technical Management & Services
							Administrative & Support
187	201	219	232	246	255	"	Administrative & Support Services

TABLE IX

LARGE PLANT
LEVEL II TREATMENT-100% REMOVAL
EQUALIZATION, CHEMICAL ADDITION, SEDIMENTATION FILTRATION, REVERSE OSMOSIS, DEEP WELL INJECTION

1969	1970	1971	1972	1973	1974		
							Operation
810	2829	3028	3123	3210	3271	Man-Hrs/Yr.	Waste Treatment Plant Operator
7.70	7.75	8.30	8.56	8.79	8.96	Man-Hrs/Day	
909	4025	4280	4439	4568	4659	Man-Hrs/Yr.	Waste Treatment Plant Attendant
10.71	11.03	11.73	12.16	12.52	12.76	Man-Hrs/Day	
3614	3743	4011	4180	4342	4445	Man-Hrs/Yr.	Waste Treatment Plant Worker
9.90	10.25	10.99	11.45	11.90	12.18	Man-Hrs/Day	
							Maintenance
406	421	447	465	484	494	Man-Hrs/Yr.	Instrument Repairman
946	976	1017	1051	1083	1110	"	Water Pump Serviceman
754	779	815	844	870	893	"	Maintenance Mechanic
403	418	444	462	481	491	"	Pipe Fitter, Maintenance
406	421	447	465	484	494	"	Electrician, Maintenance
							Other Maintenance
							Technical Management & Services
977	1007	1072	1113	1150	1176	"	Laboratory Technician
1145	1180	1246	1292	1331	1362	"	Technical Management & Services
							Administrative & Support
1193	1229	1304	1352	1396	1427	"	Administrative & Support Services

TABLE X

SMALL PLANT
LEVEL I TREATMENT-27% REMOVAL
EQUALIZATION, CHEMICAL ADDITION, LAGOON
TOTAL EFFLUENT ASSUMED DISCHARGED TO MUNICIPAL SEWERS

1969	1970	1971	1972	1973	1974		
							Operation
141	122	129	132	136	139	Man-Hrs/Yr.	Waste Treatment Plant Operator
.31	.33	.35	.36	.37	.38	Man-Hrs/Day	
233	250	264	270	277	284	Man-Hrs/Yr.	Waste Treatment Plant Attendant
.64	.68	.72	.74	.76	.78	Man-Hrs/Day	
236	253	267	273	280	287	Man-Hrs/Yr.	Waste Treatment Plant Worker
.65	.69	.73	.75	.77	.79	Man-Hrs/Day	
							Maintenance
21	22	23	24	24	25	Man-Hrs/Yr.	Instrument Repairman
26	27	28	29	29	30	"	Water Pump Serviceman
24	25	26	27	27	28	"	Maintenance Mechanic
23	24	25	26	26	27	"	Pipe Fitter, Maintenance
21	22	23	24	24	25	"	Electrician, Maintenance
10	10	10	10	10	10	"	Other Maintenance
							Technical Management & Services
58	62	65	67	69	70	"	Laboratory Technician
54	58	61	63	65	66	"	Technical Management & Services
							Administrative & Support
64	68	72	73	75	77	"	Administrative & Support Services

TABLE XI

NUMBER OF OPERATOR PERSONNEL
ASSIGNED TO WASTE TREATMENT

	1969			1970			1971		
	OP*	A**	W***	Oper	Atnt	Wrkr	Oper	Atnt	Wrkr
LARGE PLANT Treatment Level I	.87	1.83	1.94	.94	1.97	2.08	1.04	2.16	2.27
		Σ = 4.64 mh/day			Σ = 4.99			Σ = 5.47	
Assigned OP/Plant 1/		1			1			1	
No. of Plants		464			466			471	
Total Assigned OP		464			466			471	
LARGE PLANT Treatment Level II	7.07	10.71	9.90	7.75	11.03	10.25	8.30	11.73	10.99
		28.31			29.03			31.02	
Assigned OP/Plant		4			4			4	
No. of Plants		464			466			471	
Total Assigned OP		1856			1864			1884	
SMALL PLANT Treatment Level I	.31	.64	.65	.33	.68	.69	.35	.72	.73
		1.60			1.70			1.80	
Assigned OP/Plant		1			1			1	
No. of Plants		2272			2288			2309	
Total Assigned OP		2271			2288			2309	

	1972			1973			1974		
	Oper	Atnt	Wrkr	Oper	Atnt	Wrkr	Oper	Atnt	Wrkr
LARGE PLANT Treatment Level I	1.10	2.30	2.41	1.18	2.44	2.55	1.22	2.54	2.64
		Σ = 5.81			Σ = 6.17			Σ = 6.40	
Assigned OP/Plant		1			1			1	
No. of Plants		476			481			487	
Total Assigned Op		476			481			487	
LARGE PLANT Treatment Level II	8.56	12.16	11.45	8.79	12.52	11.90	8.96	12.76	12.18
		32.17			33.21			33.90	
Assigned OP/Plant		5			5			5	
No. of Plants		476			481			487	
Total Assigned OP		2380			2405			2435	
SMALL PLANT Treatment Level I	.36	.74	.75	.37	.76	.77	.38	.78	.79
		1.85			1.90			1.95	
Assigned OP/Plant		1			1			1	
No. of Plants		2334			2361			2389	
Total Assigned OP		2334			2361			2389	

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* Waste Treatment Plant Operator
** Waste Treatment Plant Attendant
*** Waste Treatment Plant Worker
1/ Based on aggregate of all three operator classifications: (man-equivalent)

arise with waste treatment and have no qualified person available to correct the situation. By providing backup personnel, there would always be a qualified person to handle critical situations when regularly assigned operator personnel are absent due to sickness, vacations, or variations in shift assignments.

Since the number of shifts operated each day has a definite impact on the number of trained Waste Treatment Plant Operators required for backup coverage, appropriate shift factors must be used. A shift factor of 5.0 to 5.2 (5) is normally used in industrial and military applications to estimate the number of persons required for continuous three-shift operations. Multiplying this factor by the number of people required per shift (one Waste Treatment Plant Operator in this case) results in the number of workers in that classification necessary to compensate for vacations, sickness, and 40-hour work-weeks in a continuous operation. When the daily manpower requirements exceed 24 man-hours, the shift factor is not applied to the excess; backup is calculated on a one-to-one ratio for the residual. For continuous operations on less than a three-shift basis, it is normally appropriate to provide a minimum of one backup person in addition to those required on a daily basis. This approach to compensating for the shift operations of the chemical industries results in the following Table XII (using 5.0 as the shift factor):

TABLE XII

TOTAL NUMBER OF TRAINED OPERATORS REQUIRED FOR EACH WASTE TREATMENT FACILITY	ASSIGNED WASTE TREATMENT PLANT OPERATORS 1/				
	1	2	3	4	5
-for 3 Shifts	5	5	5	6	6
-for <3 Shifts	2	3	4	5	6

1/ Derived by dividing total operations man-hours per day by eight hours per day per employee, then rounding to next higher whole number.

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(5) Manpower and Organization Programming, Airways and Communications Service Manual 26-1, 1 May 1957.

According to a recent survey (6), about 64% of chemical plants operate 24 hours per day, 365 days per year. The remainder are divided among one and two-shift operations on either a five or seven-day week. For the purposes of this report, the 36% remainder is assumed to work on something less than a three-shift basis, but on a seven-day week. The following Table XIII was developed from all of the considerations previously discussed.

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(6) Toward a Clean Environment, A 1967 survey of the members of the Manufacturing Chemists Association, MCA, 1967.

TABLE XIII

NUMBER OF TRAINED WASTEWATER TREATMENT PLANT OPERATORS REQUIRED

	1969	1970	1971	1972	1973	1974
LARGE PLANTS Treatment Level I 27% Removal						
No. Tnd Op for 3 shifts	5	5	5	5	5	5
No. of 3-shift plants	297	298	301	305	308	312
Total - 3 shift	1485	1490	1505	1525	1540	1560
No. Tnd Op for < 3 shifts	2	2	2	2	2	2
No. of < 3 shift plants	167	168	170	171	173	175
Total - < 3 shift	334	336	340	342	346	350
No. Tnd Op Req for Ind.	1819	1826	1845	1867	1886	1910
LARGE PLANTS Treatment Level II 100% Removal						
No. Tnd Op for 3 shifts	6	6	6	6	6	6
No. of 3-shift plants	297	298	301	305	308	312
Total - 3 shift	1782	1788	1806	1830	1848	1872
No. Tnd Op for < 3 shifts	5	5	5	6	6	6
No. of < 3 shift plants	167	168	170	171	173	175
Total - < 3 shift	835	840	150	1026	1038	1050
No. Tnd Op Req for Ind.	2617	2628	2656	2850	2886	2922
SMALL PLANTS Treatment Level I Discharge to Sewers						
No. Tnd Op for 3 shifts	5	5	5	5	5	5
No. of 3-shift plants	1454	1464	1478	1494	1511	1529
Total - 3 shift	7270	7320	7390	7470	7555	7645
No. Tnd Op for < 3 shifts	2	2	2	2	2	2
No. of < 3 shift plants	818	824	831	840	850	860
Total - <3 shift	1636	1648	1662	1680	1700	1720
No. Tnd Op Req for Ind.	8906	8968	9052	9150	9255	9365

It must be noted in connection with the above numbers, that they are based upon 100% of the indicated size plant utilizing the treatment level shown. There is no estimate of the fraction of large plants utilizing either treatment level, except for 1969 where other considerations indicate that on the average all large plants employ Treatment Level I.

APPENDIX A

INDUSTRIAL WASTE TREATMENT PRACTICES DATA FORM

Instructions

Dictionary

Form

INDUSTRIAL WASTE TREATMENT DATA FORM

INSTRUCTIONS

The Industrial Waste Treatment Practices Data Form is to be filled out in strict accordance with these instructions, in order that the data be of maximum utility. It must be born in mind that the data will be read and processed by machine and that entries must therefore be made in the numbered fields in the proper locations and in the precise terms specified. In order to avoid unnecessary copying, all entries should be printed in block letters and large figures, preferably in red or black ink. These instructions are given for the indicated sections of each data card in order as they appear on the form.

DOCUMENT TO DATA CENTER________ BY____________ Sh.___ of___
Date Name

REVISION TO DATA CENTER________ BY____________ REV. ______
Date Name

INDUSTRIAL WASTE TREATMENT PRACTICES DATA FORM

CARD 1 GENERAL INFORMATION

The information on this card identifies the plant and the firm and is data of a permanent nature, not likely to change. The name of the individual sending the completed form or a revised form to the Data Center and the date of forwarding should be entered as indicated. The number of sheets comprising the form should be entered, as well as the number of the revision being made.

PLANT NO. ☐☐☐☐☐
1 2 3 4 5

A serial number, beginning with 00001, is to be assigned to each plant for which data are acquired. Under some circumstances, it may be preferable to treat portions of a large plant as a separate plant for the purposes of this form.

INITIAL FORM NO. ☐☐☐☐☐☐
6 7 8 9 10 11

A serial number, beginning with 000001, is to be assigned to each form filled out. The number of the first form filled out for the plant in question is to be entered here in every case.

INITIAL? ☐ Yes ☐ No

Indicate by mark (X) whether or not the form being filled out is the first for the plant in question. If other than an initial form is being completed, skip to Card 2, unless a revised form is being submitted.

INDUSTRY__________________________ S.I.C. NO. ☐☐☐☐
12 13 14 15

Describe the industry within which the plant in question falls and enter the 4-digit Standard Industrial Classification (S.I.C.) number for this industry as found in the Standard Industrial Classification Manual, Bureau of the Budget, latest edition.

FIRM____________________________ PLANT_____________________

Enter the name of the firm owning the plant in question (this may be a governmental entity or a subsidiary of another firm) and the official name of the plant.

YEAR PLANT CONSTRUCTED ☐☐☐☐
16 17 18 19

Enter the year of the initial construction at the plant site without regard to subsequent modifications.

STATE_________________ CODE ☐☐
20 21

Enter the name of the state or other territory in which the plant is located and the 2-digit code taken from the Dictionary.

CITY AND/OR COUNTY___________________ CODE ☐☐☐☐☐
22 23 24 25 26

Enter the name of the city and/or county in which the plant is located. Enter the 5-digit code from the Dictionary if such a code is listed; codes will be assigned by the Data Center as specific locations appear on completed forms and thus none will initially be listed. Source of this code will be the Zip Code as found in the United States Post Office Directory.

STATISTICAL AREA____________________________ CODE ☐☐☐
27 28 29

Enter the name of the Standard Metropolitan Statistical Area (if any) in which the plant is located. Enter the code number which is the rank number of that area as found in Statistical Abstracts of the United States, Section 34, Bureau of the Census, 88th Edition (1967).

ECONOMIC AREA________________________________ CODE ☐☐
30 31

Enter the name (if any) of the economic area in which the plant is located and enter the 2-digit code number taken from the Dictionary.

WATER RESOURCE REGION__________________________ CODE ☐☐
32 33

Enter the name of the Water Resource Region, as designated by the Office of Water Resources Research for Type I Surveys, in which the plant is located and the 2-digit code number taken from the Dictionary.

RECEIVING STREAM_______________________ CODE Major ☐☐ Minor ☐☐
34 35 36 37

Enter the name of the stream or other body of water in which plant effluents do or would discharge and the 4-digit code taken from the Dictionary; the first two digits designate the major river basin and the last two the minor river basin in which the receiving stream lies. The codes correspond to the STORET system.

DATE OF DATA ACQUISITION Month ☐☐ Year ☐☐
38 39 40 41

BASE YEAR ☐☐☐☐
42 43 44 45

Enter the month and year that data being tabulated were acquired and enter the year upon which costs are based. All cost data are to be converted to the base year shown, using the Engineering News Record Construction Cost Index or other suitable cost indicator series.

SINGLE PLANT FIRM ☐ 46 MULTIPLANT FIRM ☐ 47

Indicate by mark (X) whether the plant in question is the only plant which the firm operates or is one of two or more plants.

SIZE OF FIRM:
GROSS SALES ($1000 PER YEAR) ☐☐☐☐☐☐☐ 48 49 50 51 52 53 54

Enter the gross sales of the firm owning the plant in question in thousands of dollars per year.

SUBSIDIARY OF____ ☐ 55

Enter the name of the parent firm of the firm owning the plant and indicate by mark (X) if the firm is a subsidiary of another.

SIZE OF FIRM IN THE INDUSTRY (% OF MARKET) ☐☐☐ 56 57 58

Enter the percentage of the market that the firm owning the plant has in the indicated S.I.C. industry. Enter 000 if the firm has no substantial market position; leave blank if unknown.

SIZE OF FIRM IN THE INDUSTRY: LARGE ☐ 59 MEDIUM ☐ 60
SMALL ☐ 61

Indicate by mark (X) the relative size of the firm owning the plant as compared to other firms in the industry.

OWNERSHIP OF FIRM: PUBLICLY TRADED STOCK ☐ 62

CLOSELY HELD ☐ 63

Indicate by mark (X) whether the firm's stock is publicly traded (on an exchange or over-the-counter) or is closely held.

PUBLICLY REGULATED FIRM ☐ 64 DEFENSE-ORIENTED ☐ 65

Indicate by mark (X) if the firm is publicly regulated (such as a common-carrier or utility) and if the firm produces substantially for national defense (such as aircraft or ordnance).

REVISION DATE________________ REV. ☐☐ 78 79 END OF CARD 1 80

CARD 2 BASES FOR TREATMENT DECISIONS

The information on this card relates to the bases upon which decisions were made to institute (or not to initiate) pollution abatement measures at the plant in question.

SAME AS CARD 1 (1–11) DATA FORM NO. ☐☐☐☐☐☐ 12 13 14 15 16 17

Enter the serial number of the form being completed, which may or may not be the same as the Initial Form No. on Card 1.

DATA BY______________________________
Name

CODE Person ☐☐ 18 19 Source ☐☐ 20 21 DATE Month ☐☐ 22 23 Year ☐☐ 24 25

Enter the name of the individual completing the form and the 2-part code from the Dictionary, which classifies the individual and his source of data. Enter the month and year in which the form is completed.

BASIS OF TREATMENT STANDARDS:

COMMON LAW ☐ 26 STATUTE LAW ☐ 27 PUBLIC OPINION ☐ 28

WITHIN FIRM ☐ 29 COURTS: FEDERAL ☐ 30 STATE ☐ 31 LOCAL ☐ 32

ORDER ☐ 33 PRECEDENT ☐ 34 AGENCIES: FEDERAL ☐ 35

STATE ☐ 36 INTERSTATE ☐ 37 LOCAL ☐ 38 REGULATIONS ☐ 39

ORDER ☐ 40 CONFERENCE ☐ 41 HEARSAY ☐ 42

Indicate by mark (X) the primary basis upon which the treatment standards to be attained were determined. Note that this is the basis upon which the required effluent quality was decided, not the motive force in initiating treatment action. For example, a plant may treat too rigid standards in deference to public opinion in a case where the law or a regulatory agency would be more lenient; a plant might also agree to higher treatment standards in conference with a regulatory agency than the letter of the law required. The controlling basis is to be indicated.

ACTION INITIATION WITHIN THE FIRM:

CORPORATE____________________ CODE ☐☐☐ 43 44 45

PLANT____________________ CODE ☐☐☐ 46 47 48

Enter here the corporate or plant initiator of treatment action, i.e., who started the activity which led to the treatment action and enter the appropriate code from the Dictionary.

BASIS OF ACTION DECISION:

PUBLIC OPINION ☐ 49 LAW ☐ 50 LEGAL ACTION ☐ 51

ECONOMIC INCENTIVE ☐ 52

OTHER____________________ CODE ☐☐☐ 53 54 55

Indicate by mark (X) the principle reason for the decision to institute the treatment practices or describe the reason and enter the appropriate 3-digit code from the Dictionary.

BASIS OF TREATMENT DECISION:

LEAST COST: TOTAL ☐ 56 OPERATING ☐ 57 CAPITAL ☐ 58
ECONOMIC RETURN ☐ 59 WATER CONSERVATION ☐ 60
MINIMUM COMPLIANCE ☐ 61 ULTIMATE TREATMENT ☐ 62
OTHER ________________________________ CODE ☐☐☐ 63 64 65

Indicate by mark (X) the principle reason for the decision to utilize the chosen treatment practice or describe the reason and enter the appropriate 3-digit code from the Dictionary.

RESPONSIBILITY FOR ACTION DECISION:

CORPORATE ________________________________ CODE ☐☐☐ 66 67 68
PLANT ________________________________ CODE ☐☐☐ 69 70 71

Enter the corporate or plant source of responsibility for the decision to initiate a treatment action, i.e., who actually decided to take the action. Of interest here is the lowest management level to which such responsibility was delegated. Enter the appropriate 3-digit code from the Dictionary.

RESPONSIBILITY FOR TREATMENT DECISION:

CORPORATE ________________________________ CODE ☐☐☐ 72 73 74
PLANT ________________________________ CODE ☐☐☐ 75 76 77

Enter the corporate or plant source of responsibility for the decision as to the specific treatment utilized, i.e., who actually decided upon one treatment method in preference to other alternatives. Enter the appropriate code from the Dictionary.

SAME AS CARD 1 78 79 END OF CARD 2 80

CARD 3 PLANT PRODUCTION INFORMATION I

The information on this card is concerned with the primary products produced by the plant for sale and with the normal production schedule.

PRODUCTS:

18 21 27 30 36 39

45 48 54 57 63 66

Enter the principle products of the plant in terms as descriptive, yet inclusive, as possible; use additional Cards 3 if the space is not adequate. Enter the appropriate codes, if any, from the Dictionary; codes will be assigned by the Data Center as specific products appear on completed forms.

PRODUCTION CAPACITY:

Code	10^x	Unit		Code	10^x	Unit
			through			
23 24 25	26	27		67 68 69	70	71

Enter the yearly production capacity for each product in appropriate physical units to three significant figures, and indicate the magnitude by the power of ten multiplier. Enter the code for the physical unit taken from the Dictionary.

NUMBER OF S.I.C. REPRESENTED ABOVE________________ 72 73

From the product listings, determine the number of Standard Industrial Categories represented within the plant.

PRODUCTION SCHEDULE________________ HRS. PER MO. 74 75 76

Enter the number of hours per month during which the plant normally operates production facilities on the basis of 730 hours per average month.

REMARKS: Describe here any significant peculiarities of this plant's production processes, product mix, etc.

NO. OF CARDS 3 [ ] 77 — SAME AS CARD 2 (78–79) — END OF CARD 3 (80)

Enter in field number 77 the number of Cards 3 completed for this form.

CARD 4 PLANT PRODUCTION INFORMATION II

The information on this card relates to production processes, plant size and age, level of production technology, and raw materials. Use additional Cards 4 only if the space is inadequate for an item.

PRIMARY WASTE-PRODUCING PRODUCTION PROCESSES: 18 - - - 41

Enter the six principle waste-producing production processes in terms as descriptive, yet inclusive, as the space will allow. Enter the appropriate codes, if any, from the Dictionary; codes will be assigned by the Data Center as specific processes appear on completed forms.

SIZE OF PLANT:

EMPLOYMENT 42 43 44 — 10^x 45

VALUE ADDED (DOLLARS/YR) 46 47 48 — 10^x 49

Enter the total employment within the plant, including management and administrative employees, and indicate the magnitude by the power of ten multiplier.

PLANT AREA (ACRES)__________________________ 50 51 52 53

PRODUCTION_______________________ CODE Amount 54 55 56 — 10^x 57 — Unit 58

Enter the total plant area in acres and the yearly production of the plant in appropriate physical units to three significant figures and indicate the magnitude using the power of ten multiplier. Enter the code for the physical unit taken from the Dictionary.

SIZE IN THE INDUSTRY: SMALL ☐ 59 MEDIUM ☐ 60 LARGE ☐ 61

Indicate by mark (X) the relative size of the plant in comparison to others within the industry.

AGE OF PLANT:

AGE IN YEARS ☐☐ 62 63 YEARS SINCE MAJOR MODIFICATION ☐☐ 64 65

Enter the age of the plant in years and the number of years since a major modification, in terms of the production facilities.

LEVEL OF TECHNOLOGY:

OLD ☐ 66 AVERAGE ☐ 67 ADVANCED ☐ 68

TYPICAL ☐ 69 UNIQUE ☐ 70

Indicate by mark (X) whether the production technology used in the plant is old, average, or advanced in comparison to other plants in the industry and whether the technology is typical or unique for that size plant in the industry.

RAW MATERIALS USED: ☐☐ 71 72 - - - - - - - - - - - - ☐☐ 75 76

Enter the principle raw materials used in the production processes using the appropriate codes from the Dictionary.

NO. OF CARDS 4☐ 77 [SAME AS CARD 3] 78 79 END OF CARD [4] 80

Enter in the field number 77 the number of Cards 4 completed for this form.

PRIMARY PURPOSE	MAJOR SOURCE	COST (¢/1000 GAL USED)		PRINCIPLE TREATMENT	USE (10^{4}gd)
		TOTAL	TREATMENT		
______	______	______	______	______	______
______	______	______	______	______	______
	Codes			Codes	
TOTAL COOLING	☐☐☐ 18 19 20	☐☐.☐ 21 22 23	☐☐.☐ 24 25 26	☐☐☐ 27 28 29	☐☐☐ 30 31 32
TOTAL PROCESS	☐☐☐ 33 34 35	☐☐.☐ 36 37 38	☐☐.☐ 39 40 41	☐☐☐ 42 43 44	☐☐☐ 45 46 47
TOTAL OTHER	☐☐☐ 48 49 50	☐☐.☐ 51 52 53	☐☐.☐ 54 55 56	☐☐☐ 57 58 59	☐☐☐ 60 61 62

Tabulate the indicated information for each major, separately identifiable water use within the plant and summarize as totals or weighted average the information indicated for cooling, process, and all other purposes. Note that costs are to be in cents per 1000 gallons used to tenths of a cent, i.e., the total costs of using water or the total treatment costs divided by the total used (not the total taken in unless reuse or recirculation is zero). Enter the codes taken from the Dictionary for the major sources for each use and for the major treatments for each use.

TOTAL WATER INTAKE_______________ (10^{4}gd) ☐☐☐ 63 64 65 10^x ☐ 66

Enter the total volume of water taken into the plant from all sources to three significant figures and indicate the magnitude using the power of ten multiplier.

TOTAL WATER USE_______________ (10^{4}gd) ☐☐☐ 67 68 69 10^x ☐ 70

Enter the total volume of water used in the plant for all purposes and indicate the magnitude using the power of ten multiplier. The total water use is defined as the total volume of water through all individual uses, i.e., intake times the number of reuses.

PROCESS WATER QUALITY:

SATISFACTORY ☐ 71 MARGINAL ☐ 72 UNSATISFACTORY ☐ 73

____

____

Indicate by mark (X) the general acceptability of process water at the point of use (with the treatment being accorded) and describe the general quality in the space provided.

PROCESS WATER QUALITY REQUIREMENTS:

____

______________________________ CODES ☐ 74 ☐ 75 ☐ 76 ☐ 77

Describe the general quality of water needed for major process uses and enter the codes taken from the Dictionary for the 4 most critical quality parameters.

SAME AS CARD 4 (78–79) END OF CARD 5 (80)

CARD 6 CHARACTERISTICS OF WASTE STREAMS

The information on this card (of which there may be several per form) relates to the nature and volume of the various waste streams generated by the plant operations.

WASTE STREAM NO. ☐☐ 18 19 OF ☐☐ 20 21 WASTE STREAMS

The major, separately identifiable waste streams are to be numbered from 01 and a Card 5 completed for each. Enter the corresponding serial number for the waste stream being reported and the total number of such streams.

TOTAL PLANT EFFLUENT ☐ (22) CALCULATED AS WEIGHTED AVERAGE

An additional Card 5 is to be completed when there are more than one waste stream, describing the total of all waste streams as a weighted average. In this case, indicate by mark (X) in field number 22.

FLOW ______________________________ gpd ☐☐☐☐ (23 24 25 26) 10^x ☐ (27)

Enter the flow of the waste stream in gallons per day to 4 significant figures and indicate the magnitude by the power of ten multiplier.

1.-11. SPECIFIC PARAMETERS ☐ (28) - - - ☐ (70)

Enter the average concentrations of the indicated items in the waste stream in milligrams per liter; calculate as weighted averages in the case of a calculated total effluent stream.

12. OTHERS ______________ mg/l. ☐☐☐ (71 72 73) ± ☐ (74) 10^x ☐ (75) CODE ☐ (76)

Enter the total concentration of all other materials as item 12 to 3 significant figures and the magnitude by the sign and power of ten multiplier. Enter the best code from the Dictionary, i.e., the code that most nearly describes these "other" materials in total.

REMARKS: ____

____

Describe in this space any aspects of the waste stream which are unique and not adequately treated above.

NO. OF CARDS 6 ☐ (77) SAME AS CARD 5 (78–79) END OF CARD 6 (80)

Enter in field number 77 the number of Cards 6 completed for this form.

CARD 7 WASTE TREATMENT AND/OR REDUCTION PRACTICES

Information on this card (of which there may be several per form) relates to specific, separately identifiable and describable waste treatment and/or reduction practices used in the plant.

PRACTICE NO. ☐☐ OF ☐☐ PRACTICES IN USE IN PLANT
18 19 20 21

Each practice is to be numbered from 01 and a Card 6 completed for each. Enter the serial number of the practice being reported and the total number of such practices in the plant.

PRACTICE INSTITUTED IN CONNECTION WITH ABATEMENT OF POLLUTION FROM WASTE STREAM NOS. ☐☐ ☐☐ ☐☐ ☐☐
22 29

Indicate the numbers of the waste streams as given on Cards 6 for which the reported practice was instituted.

DATA ON THIS CARD IS FOR A COMPLETE TREATMENT PLANT ☐
30

Indicate by mark (X) if the data on the card is for a complete treatment plant. If the data given apply only to the unit treatments listed, leave this space blank.

UNIT TREATMENTS: ☐ - - - - - - - - - - ☐
31 45

Enter the unit treatments and their codes from the Dictionary which comprise the treatment plant or which are being reported as parts of a treatment plant or practice.

INSTALLATION DATES:

INITIAL 19 ☐☐
46 47

LAST MODIFIED 19 ☐☐
48 49

Enter the year in which the practice was first installed or initiated and the year of the last significant modification.

SIZE AND/OR LOADINGS: ☐ 50 - - - - - - ☐ 61

Indicate the size and/or loading of the treatment in appropriate units to 3 significant figures and enter the unit's code taken from the Dictionary.

CAPITAL COST ______________________ $ ☐☐☐ 62 63 64 10^x ☐ 65

LAND VALUE ________________________ $ ☐☐☐ 66 67 68 ☐ 69

OPERATING COSTS ___________________ $/YR. ☐☐☐ 70 71 72 ☐ 73

Indicate the costs in dollars for land and capital equipment and operating costs in dollars per year to 3 significant figures and indicate the absolute amounts by the power of ten multiplier. Operating costs include all costs such as labor, chemicals, utilities, etc., but exclude amortization and depreciation.

EFFICIENCY, % ☐☐ 74 75 ON BASIS OF ______________ CODE ☐ 76

Indicate the percentage efficiency of the reported practices, the basis of efficiency measurement, and enter the code from the Dictionary describing that basis.

NO. OF CARDS 7 ☐ 77 | SAME AS CARD 6 | 78 79 END OF CARD | 7 | 80

Enter in field number 77 the number of Cards 7 completed for this form.

CARD 8 CHARACTERISTICS OF SLUDGES

The information on this card (of which there may be several per form) describes the sludges produced in the plant, treatment and disposal methods, and sludge handling costs.

SLUDGE SOURCE NO. ☐☐ OF
18 19

☐☐ SLUDGE SOURCES IN PLANT
20 21

The major, separately identifiable sources of sludge in the plant are to be numbered from 01 and a Card 7 completed for each.

TOTAL OF SLUDGES IN PLANT ☐ CALCULATED AS AN AVERAGE
22

An additional Card 7 is to be completed which describes the total of the sludges produced in the plant as a calculated weighted average; in this case indicate by mark (X) in field number 22.

QUANTITY________________________ lb/day ☐☐☐☐ 10^x ☐
23 24 25 26 27

Indicate the quantity of sludge produced in pounds of dry solids per day to 4 significant figures and indicate the magnitude by a power of ten multiplier.

DESCRIPTION OF SLUDGE:

____

____ CODE ☐☐☐☐
28 29 30 31

Describe the sludge and enter the appropriate descriptive code from the Dictionary.

TREATMENT OF SLUDGE:

____

____ CODE ☐☐☐☐
32 33 34 35

Describe the in-plant treatment of sludge and enter the appropriate descriptive code from the Dictionary.

DISPOSAL OF SLUDGE:

____

____ CODE ☐☐☐☐ 36 37 38 39

Describe the sludge disposal method utilized and enter the appropriate descriptive code from the Dictionary.

			10^x
CAPITAL COST ________________________	$	☐☐☐ 40 41 42	☐ 43
LAND VALUE __________________________	$	☐☐☐ 44 45 46	☐ 47
OPERATING COSTS _____________________	$/YR.	☐☐☐ 48 49 50	☐ 51

Indicate the costs in dollars for land and capital equipment and operating costs in dollars per year to 3 significant figures and indicate the absolute amounts by the power of ten multiplier. Operating costs include all costs such as labor, chemicals, utilities, transportation, etc., but exclude amortization and depreciation.

ULTIMATE DISPOSAL ☐ 52 SATISFACTORY ☐ 53

MARGINAL ☐ 54 UNSATISFACTORY ☐ 55

Indicate by mark (X) if the sludge disposal method is ultimate and similarly an appraisal of the degree to which the entire sludge handling method reported is considered satisfactory in general.

NO. OF CARDS 8☐ 77 [SAME AS CARD 7] 78 79 END OF CARD [8] 80

Enter in field number 77 the number of Cards 8 completed for this form.

CARD 9 APERTURE CARDS

The first Card 9 is to contain a microfilm of all sheets completed for inclusion in a single form. Additional Cards 9 may be used for this purpose, if a single microfilm will not accommodate all sheets of a long form. In the latter case, print "TREATMENT PRACTICES DATA FORM" in fields 18 thru 46 and insert "001" for the code in fields 50-52.

Additional Cards 9 should be used for the microfilm storage of other documents of interest such as process flowsheets, treatment plant diagrams or flowsheets, detailed descriptive material not accommodated on other cards, etc. Print a description of the documents to be filmed on the card in fields 18 thru 46 and insert an aperture code taken from the Dictionary. It is preferred that different types of documents not be combined on a single card.

APERTURE CODE ☐☐☐ 50 51 52

NO. OF CARDS 9 ☐ 53

Enter the aperture code from the Dictionary and indicate the number of Cards 9 completed for this form.

SAME AS CARD 8 78 79

END OF CARD 9 80

CARD 10 MANPOWER UTILIZATION IN WASTE TREATMENT

The information on this card is concerned with the manpower utilized to implement waste treatment practices in the plant. Included here are the administrative functions relating to negotiations with regulatory agencies, applications for discharge permits, etc., as well as the operating and maintenance labor, technical help, and engineer inputs to design, construction, and consulting. Use separate Cards 10 for individuals who have different functions, levels of education, trades or professions, employment status, or work areas.

FUNCTION:

Administration ☐ 18
Analysis ☐ 19
Operation ☐ 20
Maintenance ☐ 21
Supervision ☐ 22
Operator ☐ 23
Technician ☐ 24
Laborer ☐ 25
ENGINEERING: Process Design ☐ 26
Plant Design ☐ 27
Consultant ☐ 28

Indicate by mark (X) the function(s) which describes that of the individual(s) reported on a single Card 10. More than one field may be checked; for example, a laborer in maintenance would be indicated by X's in fields 25 and 21, or a technician in an analytical laboratory by X's in fields 19 and 24. Include on a single Card 10 only individuals who have identical functions; use additional Cards 10 for other functions.

OTHER________________________________ CODE ☐☐☐ 29 30 31

Describe specialized functions which cannot be adequately described as above and enter the appropriate 3-digit code from the Dictionary.

EDUCATION AND/OR EXPERIENCE:

COLLEGE: B.S. ☐ 32 M.S. ☐ 33 PH.D. ☐ 34 1 YR. ☐ 35
2 YRS. ☐ 36 3 YRS. ☐ 37 JUNIOR COLLEGE ☐ 38
HIGH SCHOOL ☐ 39 TECHNICAL SCHOOL ☐ 40
GRADE SCHOOL ☐ 41

Indicate by a mark (X) the highest level of education of the individual(s) reported on this Card 10. Do not check more than one field.

YEARS WORKING EXPERIENCE________________________ ☐☐ 42 43
YRS. IN SPECIALTY____________________________ ☐☐ 44 45

Enter the years of total working experience and the years experience in the reported function for an individual on a single Card 10. If more than one individual is reported on a single Card 10, use the average figures in each case.

TRADE OR PROFESSION_______________________ CODE ☐☐☐ 46 47 48

Describe the trade or profession of the individual(s) reported on this Card 10 and enter the appropriate 3-digit code from the Dictionary.

WORK LEVELS AND COSTS:

NO. OF PERSONS ______________________________ ☐☐ 49 50

MAN-HOURS PER MONTH __________________________ ☐☐☐☐ 51 52 53 54

COSTS PER MAN-HOUR: WAGES ____________________ $ ☐☐ 55 56 ☐☐ 57 58

TOTAL _______________________________________ $ ☐☐ 59 60 ☐☐ 61 62

Enter the number of persons reported on this Card 10 and the total number of man-hours per month devoted to the reported function by this individual(s). Enter the wages received by the individual per hour and the total employment cost to the employer per hour; if more than one individual is reported on a single Card 10, use the average figures in each case.

EMPLOYMENT STATUS:

FULL-TIME EMPLOYEE ☐ 63

PART-TIME EMPLOYEE ☐ 64

OUTSIDE _____________________________________ ☐ 65

% OF EMPLOYED TIME DEVOTED TO WASTE TREATMENT _____ ☐☐ 66 67 %

UNION MEMBER ☐ 68

EXEMPT EMPLOYEE ☐ 69

NON-EXEMPT EMPLOYEE ☐ 70

Indicate by mark (X) whether the individual is a full-time or part-time employee of the firm or is employed outside of the firm. Indicate the percent of employed time devoted to activities relating to waste treatment in the plant, in the broad sense described above. Indicate by mark (X) if the reported individual is a union member and whether or not he is exempt from the provisions of the Wages and Hours Act.

WORK AREA:

COMPANY GENERAL ☐ 71

PLANT GENERAL ☐ 72

WASTE TREATMENT PLANT ☐ 73

Indicate by mark (X) whether the work level reported on this Card 10 may be considered to be on behalf of the entire firm, the specific plant, or to waste treatment specifically. If the work reported on this Card 10 can be considered to apply to a single waste treatment process, describe it and enter the appropriate 3-digit code from the Dictionary.

REMARKS:

Describe here any peculiarities of the reported situation not adequately described above.

NO. OF CARDS 10		SAME AS CARD 9	END OF CARD	10
	77	78 79		80

Enter in field number 77 the number of Cards 10 completed for this form.

INDUSTRIAL WASTE TREATMENT DATA FORM

DICTIONARY

If any entry cannot be adequately described by a code number in the Dictionary, the code fields are to be left blank; such codes will be assigned by the Data Center. However, all information pertaining to the question should be recorded in the space provided for use by the Code Center. In no case should a code be used which is not in the Dictionary.

CARD 1 ☐☐☐☐ Standard Industrial Category
12 13 14 15

- 26 PAPER AND ALLIED PRODUCTS
  - 261 Pulp Mills
    - 2611 Pulp mills
  - 262 Paper Mills, Except Building Paper Mills
    - 2621 Paper mills, except building paper mills
  - 263 Paperboard Mills
    - 2631 Paperboard mills
  - 264 Converted Paper and Paperboard Products, Except Containers and Boxes
    - 2641 Paper coating and glazing
    - 2642 Envelopes
    - 2643 Bags, except textile bags
    - 2644 Wallpaper
    - 2645 Die cut paper and paperboard; and cardboard
    - 2646 Pressed and molded pulp goods
    - 2647 Sanitary paper products
    - 2649 Converted paper and paperboard products, not elsewhere classified
  - 265 Paperboard Containers and Boxes
    - 2651 Folding paperboard boxes
    - 2652 Set-up paperboard boxes
    - 2653 Corrugated and solid fiber boxes
    - 2654 Sanitary food containers
    - 2655 Fiber cans, tubes, drums, and similar products
  - 266 Building Paper and Building Board Mills
    - 2661 Building paper and building board mills

- 28 CHEMICALS AND ALLIED PRODUCTS
  - 281 Industrial Inorganic and Organic Chemicals
    - 2812 Alkalies and chlorine
    - 2813 Industrial gases
    - 2815 Dyes, dye (cyclic) intermediates, organic pigments (lakes and toners) and cyclic (coal tar) crudes

    - 2816 Inorganic pigments
    - 2818 Industrial organic chemicals, not elsewhere classified
    - 2819 Industrial inorganic chemicals, not elsewhere classified
  - 282 Plastics Materials and Synthetic Resins, Synthetic Rubber, Synthetic and Other Man-Made Fibers, Except Glass
    - 2821 Plastics materials, synthetic resins, and nonvulcanizable elastomers
    - 2822 Synthetic rubber (vulcanizable elastomers)
    - 2823 Cellulosic man-made fibers
    - 2824 Synthetic organic fibers, except cellulosic
  - 283 Drugs
    - 2831 Biological products
    - 2833 Medicinal chemicals and botanical products
    - 2834 Pharmaceutical preparations
  - 284 Soap, Detergents, and Cleaning Preparations, Perfumes, Cosmetics, and Other Toilet Preparations
    - 2841 Soap and other detergents, except specialty cleaners
    - 2842 Specialty cleaning, polishing, and sanitation preparations, except soap and detergents
    - 2843 Surface active agents, finishing agents, sulfonated oils and assistants
    - 2844 Perfumes, cosmetics, and other toilet preparations
  - 285 Paints, Varnishes, Lacquers, Enamels, and Allied Products
    - 2851 Paints, varnishes, lacquers, enamels and allied products
  - 286 Gum and Wood Chemicals
    - 2861 Gum and wood chemicals
  - 287 Agricultural Chemicals
    - 2871 Fertilizers
    - 2872 Fertilizers, mixing only
    - 2879 Agricultural pesticides, and other agricultural chemicals, not elsewhere classified
  - 289 Miscellaneous Chemical Products
    - 2891 Adhesives and gelatin
    - 2892 Explosives
    - 2893 Printing ink
    - 2895 Carbon black
    - 2899 Chemicals and chemical preparations, not elsewhere classified

- 29 PETROLEUM REFINING AND RELATED INDUSTRIES
  - 291 Petroleum Refining
    - 2911 Petroleum refining

- 295 Paving and Roofing Materials
    - 2951 Paving mixtures and blocks
    - 2952 Asphalt felts and coatings
- 299 Miscellaneous Products of Petroleum and Coal
    - 2992 Lubricating oils and greases
    - 2999 Products of petroleum and coal, not elsewhere classified

33 PRIMARY METAL INDUSTRIES

- 331 Blast Furnaces, Steel Works, and Rolling and Finishing Mills
    - 3312 Blast furnaces (including coke ovens), steel works, and rolling mills
    - 3313 Electrometallurgical products
    - 3315 Steel wire drawing and steel nails and spikes
    - 3316 Cold rolled steel, sheet, strip, and bars
    - 3317 Steel pipe and tubes
- 332 Iron and Steel Foundries
    - 3321 Gray iron foundries
    - 3322 Malleable iron foundries
    - 3323 Steel foundries
- 333 Primary Smelting and Refining of Nonferrous Metals
    - 3331 Primary smelting and refining of copper
    - 3332 Primary smelting and refining of lead
    - 3333 Primary smelting and refining of zinc
    - 3334 Primary production of aluminum
    - 3339 Primary smelting and refining of nonferrous metals, not elsewhere classified
- 334 Secondary Smelting and Refining of Nonferrous Metals
    - 3341 Secondary smelting and refining of nonferrous metals
- 335 Rolling, Drawing and Extruding of Nonferrous Metals
    - 3351 Rolling, drawing, and extruding of copper
    - 3352 Rolling, drawing, and extruding of aluminum
    - 3356 Rolling, drawing, and extruding of nonferrous metals, except copper and aluminum
    - 3357 Drawing and insulating of nonferrous wire
- 336 Nonferrous Foundries
    - 3361 Aluminum castings
    - 3362 Brass, bronze, copper, copper base alloy castings
    - 3369 Nonferrous castings, not elsewhere classified
- 339 Miscellaneous Primary Metal Products
    - 3391 Iron and steel forgings
    - 3392 Nonferrous forgings
    - 3399 Primary metal products, not elsewhere classified

CARD 1 ☐☐ State Codes
20 21

01	Alabama
02	Alaska
03	Arizona
04	Arkansas
05	California
06	Colorado
07	Connecticut
08	Delaware
09	District of Columbia
10	Florida
11	Georgia
12	Hawaii
13	Idaho
14	Illinois
15	Indiana
16	Iowa
17	Kansas
18	Kentucky
19	Louisiana
20	Maine
21	Maryland
22	Massachusetts
23	Michigan
24	Minnesota
25	Mississippi
26	Montana
28	Nebraska
29	Nevada
30	New Hampshire
31	New Jersey
32	New Mexico
33	New York
34	North Carolina
35	North Dakota
36	Ohio
37	Oklahoma
38	Oregon
39	Pennsylvania
40	Rhode Island
41	South Carolina
42	South Dakota
43	Tennessee
44	Texas
45	Utah
46	Vermont
47	Virginia
48	Washington
49	West Virginia
50	Wisconsin
51	Wyoming
52	Puerto Rico
53	American Samoa
54	Canal Zone
55	Guam
56	U.S. Virgin Islands
57	Pacific Islands Trust Territories

CARD 1

CITY AND/OR COUNTY ____________________ CODE ☐☐☐☐☐
22 23 24 25 26

This code will correspond to the post office ZIP code for the plant location, e.g., Crafton, Pennsylvania 15205

1	5	2	0	5
22	23	24	25	26

CARD 1

STATISTICAL AREA ____________________ CODE ☐☐☐
27 28 29

Rank No.	City
045	Akron, Ohio
093	Albany, N.Y.
059	Albuquerque, N. Mex.
116	Allentown, Pa.
088	Amarillo, Tex.
123	Anaheim, Calif.
024	Atlanta, Ga.
067	Austin, Tex.
006	Baltimore, Md.
080	Baton Rouge, La.
102	Beaumont, Tex.
114	Berkeley, Calif.
036	Birmingham, Ala.
013	Boston, Mass.
079	Bridgeport, Conn.
020	Buffalo, N.Y.
119	Cambridge, Mass.
103	Camden, N.J.
109	Canton, Ohio
058	Charlotte, N.C.
092	Chattanooga, Tenn.
002	Chicago, Ill.
021	Cincinnati, Ohio
008	Cleveland, Ohio
104	Columbus, Ga.
028	Columbus, Ohio
074	Corpus Christi, Tex.
014	Dallas, Tex.
049	Dayton, Ohio
110	Dearborn, Mich.
023	Denver, Colo.
055	Des Moines, Iowa
005	Detroit, Mich.
122	Duluth, Minn.
120	Elizabeth, N.J.
046	El Paso, Tex.
087	Erie, Pa.
086	Evansville, Ind.
061	Flint, Mich.
078	Fort Wayne, Ind.
034	Fort Worth, Tex.
090	Fresno, Calif.
070	Gary, Ind.
101	Glendale, Calif.
071	Grand Rapids, Mich.
099	Greensboro, N.C.
112	Hammond, Ind.
077	Hartford, Conn.
043	Honolulu, Hawaii
007	Houston, Texas
026	Indianapolis, Ind.
084	Jackson, Miss.
060	Jacksonville, Fla.
047	Jersey City, N.J.
098	Kansas City, Kans.
027	Kansas City, Mo.
111	Knoxville Tenn.
118	Lansing, Mich.
095	Lincoln, Nebr.
117	Little Rock, Ark.
035	Long Beach, Calif.
003	Los Angeles, Calif.
031	Louisville, Ky.
094	Lubbock, Tex.
096	Madison, Wis.
022	Memphis, Tenn.
044	Miami, Fla.
011	Milwaukee, Wis.
025	Minneapolis, Minn.
062	Mobile, Ala.
089	Montgomery, Ala.
073	Nashville, Tenn.
125	New Bedford, Mass.
081	New Haven, Conn.
015	New Orleans, La.
001	New York, N.Y
(X)	Bronx Borough
(X)	Brooklyn Borough
(X)	Manhattan Borough
(X)	Queens Borough
(X)	Richmond Borough
030	Newark, N.J.
108	Newport News, Va.
126	Niagara Falls, N.Y.
041	Norfolk, Va.
033	Oakland, Calif.
037	Oklahoma City, Okla.
042	Omaha, Nebr.
105	Pasadena, Calif.
085	Paterson, N.J.
124	Peoria, Ill.
004	Philadelphia, Pa.
029	Phoenix, Ariz.
016	Pittsburgh, Pa.
032	Portland, Oreg.
106	Portsmouth, Va.

Rank No.	City
056	Providence, R.I.
052	Richmond, Va.
038	Rochester, N.Y.
096	Rockford, Ill.
063	Sacramento, Calif.
010	St. Louis, Mo.
040	St. Paul, Minn.
069	St. Petersburg, Fla.
065	Salt Lake City, Utah
017	San Antonio, Tex.
018	San Diego, Calif.
012	San Francisco, Calif.
057	San Jose, Calif.
130	Santa Ana, Calif.
082	Savannah, Ga.
113	Scranton, Pa.
019	Seattle, Wash.
076	Shreveport, La.
091	South Bend, Ind.
068	Spokane, Wash.

Rank No.	City
072	Springfield, Mass.
053	Syracuse, N.Y.
083	Tacoma, Wash.
048	Tampa, Fla.
039	Toledo, Ohio
100	Topeka, Kans.
128	Torrance, Calif.
107	Trenton, N.J.
154	Tucson, Ariz.
050	Tulsa, Okla.
129	Utica, N.Y.
009	Washington, D.C.
121	Waterbury, Conn.
051	Wichita, Kans.
127	Wichita Falls, Tex.
115	Winston-Salem, N.C.
066	Worcester, Mass.
064	Yonkers, N.Y.
075	Youngstown, Ohio

See STATISTICAL ABSTRACTS OF THE UNITED STATES, Section 34, Bureau of the Census, 88th Edition (1967). The code number will be the rank number of the area.

CARD 1 ☐☐ Economic Area Codes
30 31

01	New England Metropolitan State Economic Area
02	Labor Surplus Areas
03	Appalachia

CARD 1 ☐☐ Water Resources Region Codes
32 33

01	Alaska
02	Arkansas-White-Red
03	California
04	Columbia - N. Pacific
05	Great Basin
06	Great Lakes
07	Hawaii
08	Lower Colorado
09	Lower Mississippi
10	Missouri
11	North Atlantic
12	Ohio
13	Puerto Rico-Virgin Islands
14	Rio Grande
15	Sooris-Red-Rainy
16	South Atlantic - Gulf
17	Tennessee
18	Texas - Gulf
19	Upper Colorado
20	Upper Mississippi

Major Minor
CARD 1 ☐☐ ☐☐ Receiving Stream Codes
34 35 36 37

01	NE - Northeast	
	01	Quinnipiac River & Western Connecticut Coastal
	02	Housatonic River
	03	Pawcatuck River & Eastern Connecticut Coastal
	04	Connecticut River
	05	Thames River
	06	Narrangansett Bay
	07	
	08	Massachusetts Coastal
	09	Merrimac River
	10	Piscatequa River & New Hampshire Coastal
	11	
	12	Saco River & South Main Coastal
	13	
	14	Presumpscot River & Casco Bay
	15	Androscoggin River
	16	Kennebec & Sheepscot Rivers
	17	Penobscot River
	18	North Maine Coastal
	19	St. Croix River
	20	St. Johns River
	21	Lake Memphremagog
	22	
	23	
	24	Lake Champlain
	25	St. Lawrence
	26	Lake Ontario Shore - Oswego River to St. Lawrence River
	27	Niagara River
	28	Genesee River
	29	Oswego River
	30	Mohawk River
	31	Upper Hudson
	32	Middle Hudson
	33	Lower Hudson - New York Metropolitan Area
	34	New Jersey Coast
	35	Lake Erie Shore & Minor Tributaries
	36	Lake Ontario Shore - Genesee River to Oswego River
	37	Lake Ontario Shore - Niagara River to Genesee River
	38	St. Regis River
02	NA - North Atlantic	
	03	Delaware River Basin - Zone 1
	04	Delaware River Basin - Lehigh

  - 05 Delaware River Basin - Schuylkill
  - 06 Delaware River Basin - Zone 2
  - 07 Delaware River Basin - Zone 3
  - 08 Delaware River Basin - Zone 4
  - 09 Susquehanna River - North Branch
  - 10 Susquehanna River - West Branch
  - 11 Susquehanna River - Juniata
  - 12 Susquehanna River - Main Stem
  - 13 Upper Chesapeake Bay & Maryland-Delaware Coast
  - 14 Potomac River
  - 15 Rappahannock & York Rivers - Virginia Coast
  - 16 James River

- 03 SE - Southeast
  - 01 Chowan River
  - 02 Roanoke River
  - 03 Tar River
  - 04 Neuse River
  - 05 North Carolina Coastal Area
  - 06 Cape Fear River
  - 07 Yadkin-Pee Dee River
  - 08 Pee Dee River - Lower Pee Dee River
  - 09 Catawha-Wateree River
  - 10 Congaree River
  - 11 Santee-Cooper River
  - 12 Edisto-Combahee River
  - 13 Savannah River
  - 14 Ogeechee River
  - 15 Ocomee River
  - 16 Ocmulgee River
  - 17 Altamaha River
  - 18 Satilla River
  - 19 St. Marys-Nassau River
  - 20 St. Johns River
  - 21 Suwanee River
  - 22 Ochlockonee-St. Marks River
  - 23 Withalcoochee River
  - 24 Tampa Bay Area
  - 25 Pease River
  - 26 Kissimmee River
  - 27 Florida East Coastal Area
  - 28 Lower Florida Area
  - 29 Flint River
  - 30 Chattachoochee River
  - 31 Apalachicola River
  - 32 Choctawhatchee River
  - 33 Perdido-Escambia River
  - 34 Tallapoosa River
  - 35 Coosa River
  - 36 Cahaba River
  - 37 Alabama River

- 38 Upper Tombigbee River
- 39 Warrior River
- 40 Lower Tombigbee River
- 41 Mobile Bay Area
- 42 Pasacagoula River
- 43 Pearl River

04 TR - Tennessee River
- 01 Clinch
- 02 Holston
- 03 French Broad
- 04 Little Tennessee
- 05 Hiwassee
- 06 Elk
- 07 Duck
- 08 Main Stem, Tennessee River & Minor Tributaries

05 OR - Ohio River
- 01 Allegheny
- 02 Monongahela
- 30 Beaver
- 04 Muskingum
- 05 Little Kanawaha
- 06 Hocking
- 07 Kanawha
- 08 Gayandot
- 09 Big Sandy
- 10 Scioto
- 11 Little Miami
- 12 Licking
- 13 Miami
- 14 Kentucky
- 15 Salt
- 16 Green
- 17 Wabash
- 18 East Fork White River
- 19 West Fork White River
- 20 Cumberland
- 21 Ohio Main Stem & Minor Tributaries
- 22 French Creek
- 23 Clarion River

06 LE - Lake Erie
- 01 Maumee
- 02 Sandusky
- 03 Cuyahoga
- 04 Lake Erie Shore - Maumee River to Sandusky River
- 05 Lake Erie Shore - Sandusky River to Cuyahoga River

- 06 Lake Erie Shore - Cuyahoga River to N.Y. State Line

07 UM - Upper Mississippi
- 01 Red River of the North
- 02 Rainy
- 03 Upper Portion Upper Mississippi River
- 04 Minnesota
- 05 St. Croix
- 06 Lower Portion Upper Mississippi River
- 07 Wisconsin
- 08 Mississippi-Wapsipinicon & Tributaries
- 09 Rock
- 10 Mississippi-Iowa-Cedar
- 11 Mississippi-Des Moines-Skunk
- 12 Mississippi-Salt
- 13 Chicago-Calumet
- 15 Kankakee
- 16 Fox
- 17 Illinois
- 18 Mississippi-St. Louis Area
- 19 Meramec
- 20 Kaskaskia
- 21 Big Muddy
- 22 Mississippi-Cape Girardeau Area

08 WL - Western Great Lakes
- 23 Lake Superior
- 24 Green Bay Western Shore
- 25 Fox-Wolf
- 26 Lake Michigan Western Shore (Includes North Suburbs of Chicago which drain to Lake)
- 27 Lake Michigan-Lake Huron North Shore
- 28 Lake Michigan Northeastern Shore
- 29 Muskegon River
- 30 Grand River
- 31 Kalamazoo
- 32 St. Joseph River
- 33 Lake Huron Western Shore
- 34 Saginaw River
- 35 Lake St. Clair & St. Clair River
- 36 Lake Erie Western Shore-Detroit River
- 37 Lake Huron-North Shore
- 49 Calumet-Burns Ditch Complex

09 MR - Missouri River
- 01 Upper Missouri (Main Stem & Tributaries to below mouth of Milk River)

02 Yellowstone
03 Missouri-Souris
(Main Stem & Minor Tributaries from mouth of Milk River to Spring Creek including Devils Lake & Souris River)
04 Central Missouri
(Main Stem & Tributaries from above mouth of Spring Creek to Niobrara River)
05 Niobrara
06 James
07 Big Sioux
08 Lower Platte
(Platte River from its origin at North Platte, Nebraska, to its mouth)
09 North Platte
10 South Platte
11 Kansas
12 Lower Missouri
(Main Stem & Minor Tributaries from Niobrara River to mouth)
13 Grand-Chariton
14 Osage-Casconade

10 SM - Southwest-Lower Mississippi
01 Upper Arkansas River above Kansas-Colorado State Line
02 Arkansas River-Kansas-Colorado State Line to Tulsa
03 Verdigris River
04 Grand (Nesho) River
05 White River
06 Lower Mississippi River-Cairo to Helena, Arkansas
07 Cimarron River
(New Mexico-Colorado-Kansas & Oklahoma)
08 North Canadian River
09 Arkansas River-Tulsa to Van Buren
10 Arkansas River-Van Buren to Mouth
11 Lower Mississippi River-Yazoo River
12 South Canadian River-above Texas-Oklahoma State Line
13 South Canadian River-below Texas-Oklahoma State Line
14 Washita River
15 Upper Red River-above Denison
16 Lower Red River-below Denison
17 Ouachita River
18 Lower Mississippi River-Big Black River
19 Atchafalaya River
20 Calcasieu River

- 21 Lower Mississippi River-Natchez to Gulf

11 CR - Colorado River

- 01 Lower Colorado River Basin
- 02 Middle Colorado-San Juan River Basin
- 03 Upper Colorado River
- 04 Gila River
- 05 Little Colorado River
- 06 Green River Basin

12 WG - Western Gulf

- 01 Sabin River
- 02 Neches River
- 03 Trinity & San Jacinto
- 04 Brazos
- 05 Colorado
- 06 Guadelupe, Lavaca, & San Antonio Basin
- 07 Nueces River
- 08 Pecos (Upper)
- 09 Rio Grande (Upper) above Pecos River
- 10 Rio Grande (Lower) below Pecos River

13 PN - Pacific Northwest

- 01 Kootenai
- 02 Clark Fork-Pend Oreille River
- 03 Spokane
- 04 Yakima
- 05 Columbia River Basin above Yakima River
- 06 Upper Snake River
- 07 Central Snake River
- 08 Middle & Lower Snake River
- 09 Willamette River
- 10 Columbia River below Yakima River
- 11 Puget Sound
- 12 Washington Coast
- 13 Oregon Coast
- 14 Southern Oregon Lakes

14 CL - California

- 01 Klamath River
- 02 North Coastal
- 03 San Francisco Bay Region
- 04 Central Coastal
- 05 Santa Clara River
- 06 Los Angeles
- 07 Santa Ana River
- 08 San Diego
- 09 Sacramento River
- 10 San Joaquin River
- 11 Kings & Kern Rivers & Tulare Lake

15 GB - Great Basin
  01 Northwestern Lahontan
  02 Humboldt River
  03 Central Nevada
  04 Owens River
  05 Mojave
  06 Colorado River Basin Region of California
  07 Great Salt Lake
  08 Sevier River

16 AL - Alaska
  01 Southeast Alaska
  02 North Pacific Ocean
  03 Bering Sea
  04 Huskokwim River
  05 Yokon River
  06 Arctic Ocean
  07 Noatak-Kobuk Rivers

17 HA - Hawaii
  01 Hawaii County (Hawaii Island)
  02 Honolulu County (Oahu Island)
  03 Kauai County (Kauai, Niihau, and small islands)
  04 Maui - Kalawao Counties (Maui, Molokai, Lanai & Kahoolawe, and small islands)

18 PR - Puerto Rico

19 VI - Virgin Islands

	Person	Source	
CARD 2	☐☐	☐☐	CODES FOR INDIVIDUALS COMPLETING FORMS
	18 19	20 21	

PERSON

01 FWPCA Personnel
02 Consultant
03 Plant Personnel
04 Corporate Personnel
05 Plant Pollution Engineer
06 State Pollution Personnel
07 Environmental Control Personnel
08 Plant Chemist
09 Legal Counsel

SOURCE OF DATA

01 Plant Interview
02 Corporate Interview
03 Plant Files
04 Corporate Files
05 Consultant Files
06 FWPCA Files
07 Literature References
08 Trade Organization
09 State Wastewater Permit

CARD 2 ☐☐☐ CODES FOR CORPORATE ACTION INITIATION
43 44 45

001	Corporate Management
002	Corporate Legal Counsel
003	Corporate Public Relations Department
004	Corporate Pollution Department or Specialist
005	Corporate Engineering Department
006	Corporate Environmental Control Department
007	Corporate Pollution Consultant
008	Corporate Production Department

CARD 2 ☐☐☐ CODES FOR PLANT ACTION INITIATION
46 47 48

001	Plant Management
002	Plant Pollution Department or Specialist
003	Plant Production Department
004	Plant Labor Representatives
005	Treatment Plant Manager
006	Plant Maintenance or Utilities Departments
007	Plant Engineering Department
008	Plant Pollution Consultant

CARD 2 ☐☐☐ CODES FOR BASIS OF ACTION DECISION
53 54 55

001	Insufficient Water Supply
002	Increase Production
003	Present Treatment Results in Equipment Failure
004	Public Relations in Community
005	Conservation Program
006	Cooperation with Local Industry
007	Product Recovery for Sale
008	Changes in Plant Layout

CARD 2 ☐☐☐ CODES FOR ADDITIONAL BASES OF TREATMENT DECISIONS
63 64 65

001	Land Available for Treatment Practice
002	Generally Accepted Method for Waste Treatment
003	Providing Water Acceptable for Recycle
004	Within Pollution Control Budget
005	Tax Allowance
006	Expected Process Life
007	Consultants Recommendations
008	Least Manpower Requirements
009	Estimated Future Pollution Requirements

CARD 2 ☐☐☐ CODES FOR CORPORATE ACTION DECISION RESPONSIBILITY
66 67 68

001	Corporate Management
002	Corporate Legal Counsel
003	Corporate Public Relations Department
004	Corporate Pollution Department or Specialist
005	Corporate Engineering Department

CARD 2 ☐☐☐ CODES FOR PLANT ACTION DECISION RESPONSIBILITY
69 70 71

001	Plant Management
002	Plant Pollution Department or Specialist
003	Plant Production Department
004	Plant Public Relations Department
005	Treatment Plant Manager
006	Plant Maintenance or Utilities Departments
007	Plant Engineering Department

CARD 2 ☐☐☐ CODES FOR CORPORATE TREATMENT DECISION
72 73 74

001	Corporate Management
002	Corporate Pollution Department or Specialist
003	Corporate Engineering Department
004	Consultant Reporting to Corporate Level
005	Contractor Reporting to Corporate Level
006	Vendor Reporting to Corporate Level

CARD 2 ☐☐☐ CODES FOR PLANT TREATMENT DECISION
75 76 77

001	Plant Management
002	Plant Pollution Department or Specialist
003	Plant Production Department
004	Plant Engineering Department
005	Plant Maintenance or Utilities Departments
006	Treatment Plant Manager
007	Consultant Reporting to Plant Level
008	Contractor Reporting to Plant Level
009	Vendor Reporting to Plant Level

CARD 3 ☐☐☐☐ ☐☐☐☐
18 21 27 30
☐☐☐☐ ☐☐☐☐
36 39 45 48
☐☐☐☐ ☐☐☐☐
54 57 63 66

PRODUCT CODES

0001	Chlorine
0002	Sodium Carbonate
0003	Sodium Sulfate
0004	Lithium Carbonate
0005	Potassium Chloride, Agricultural
0006	Potassium Sulfate
0007	Bromine
0008	Borax Decahydrate
0009	Sodium Sulfate, Desiccated
0010	Potassium Chloride, Chemical Grade
0011	Borax Pentahydrate
0012	Boric Acid
0013	Anhydrous Borax
0014	Sodium Pentaborate
0015	50% Sodium Hydroxide
0016	73% Sodium Hydroxide
0017	Alumina
0018	Anhydrous Ammonia
0019	Nitric Acid
0020	Ammonium Nitrate
0021	Sodium Chloride
0022	98% Sulfuric Acid
0023	Calcium Phosphate, Animal Food
0024	Phosphoric Acid
0025	Hydrochloric Acid
0026	Paint
0027	Titanium Dioxide
0028	Merchant Sodium
0029	Zinc Oxide
0030	Hydrofluoric Acid
0031	Calcium Sulfate
0032	Ammonium Sulfate
0033	Oxygen
0034	Nitrogen
0035	Argon
0036	Urea
0037	Nitrogen Solutions
0038	Urea (Prilled)
0039	Aluminum Sulfate
0040	
0041	Caustic Potash
0042	Caustic Soda
0043	Barites
0044	Calcium Carbonate
0045	Iron Oxide Pigments
0046	Calcium Carbide
0047	Hydrofluoric Acid
0048	Hydrogen Peroxide
0049	Lime
0050	Phosphorus
0051	Sodium Metal
0052	Sodium Bicarbonate
0053	Sodium Bichromate
0054	Potassium Bichromate
0055	Sodium Silicate
0056	Sodium Sulfite
0057	Sodium Tripoly Phosphate
0058	Aluminum Chloride
0059	Varnish
0060	Lacquer
0061	Ammonium Phosphate
0062	Diammonium Phosphate
0063	Superphosphates
0064	Phosphate Rock
0065	Triple Super Phosphate
0066	Potash
0067	Lead Arsenate
0068	Sulfur
0069	Carbon Bisulfide
0070	Hydrogen Cyanide
0071	Fluorine
0072	Lime-Sulfurs
0073	Bordeaux Mixture
0074	Mercuric Chloride
0075	Sodium Chlorate
0076	Sodium Arsenite
0077	Ammonium Sulfamate
0078	Nitrocellulose
0079	TNT
0080	Smokeless Powder
0081	Ammonium Nitrate
0082	Nitroglycerin
0083	Dynamite

0084	Sodium Perborate
0085	Manganese Dioxide
0086	Magnesium Oxide
0087	Calcium Oxide

CARD 3 ☐ ☐ ☐
26 35 44
☐ ☐ ☐ PRODUCTION CAPACITY CODES
53 62 71

1	Lbs per Year
2	Tons per Year
3	Gallons per Year
4	Barrels per Year
5	Cubic Feet per Year
6	Pieces per Year
7	KWH per Year

CARD 4 ☐ WASTE-PRODUCING PROCESS CODES
18 41

0001	Electrolysis
0002	Diaphragm Cell
0003	Mercury Cell
0004	Calcination
0005	Solvey Process
0006	Pressure Liquification
0007	Thermal Reduction
0008	Wet Grinding
0009	Digestion
0010	Crystallization
0011	Oxidation
0012	Electrothermic
0013	Deacon Process
0014	Kellogg Process
0015	Hargreaves Reaction
0016	Absorption
0017	Thermal Decarbonation
0018	Hydrolysis
0019	Solar Evaporation
0020	Mining
0021	Well Brine
0022	Fusing
0023	Chamber Process
0024	Contact Process
0025	Mixing Process

CARD 4 ☐ PLANT PRODUCTION UNITS CODES
58

1	Lbs per Year
2	Tons per Year
3	Gallons per Year
4	Barrels per Year
5	Cubic Feet per Year
6	Pieces per Year
7	KWH per Year

CARD 4 ☐ RAW MATERIAL CODES
71 76

01	Minerals
02	Forest Products
03	Natural Gas
04	Petroleum
05	Inorganic Chemicals
06	Organic Chemicals
07	Ores
08	Metals
09	Animal Products
10	Agricultural Products

11	Manufactured Goods
12	Petrochemicals
13	Ethylene
14	Sulfuric Acid
15	Limestone
16	Coke
17	Bauxite
18	Soda Ash
19	Starch
20	Rutile
21	Chlorine
22	Sodium
23	Phosphate Rock
24	Fluorspar
25	Mineral Trona
26	Ammonia
27	Air
28	Glycerin
29	Nitric Acid
30	Wood Flour
31	Cotton Linters
32	Lead Oxide
33	Sand
34	Well Brine
35	Salt Water
36	Rock Salt
37	Chromium Iron Oxide
38	Quicklime
39	Franklinite
40	Ilmenite
41	Natural Clays
42	Chalk

CARD 5 ☐☐☐ ☐☐☐ ☐☐☐ WATER SOURCES CODES

18 19 20 33 34 35 48 49 50

001	Company Surface Sources
002	Company Wells
003	Purchased from Municipal Waterworks
004	Sewage Plant Effluent
005	Cooling Water
006	Previously Recirculated Cooling Water
007	Process Water
008	Previously Recirculated Process Water
009	Sea Water
010	Lake

CARD 5 ☐☐☐ ☐☐☐ ☐☐☐ WATER TREATMENT CODES

27 28 29 42 43 44 57 58 59

001	None
002	Sedimentation
003	Filtration
004	Sedimentation & Filtration
005	Softening
006	Sedimentation & Softening
007	Filtration & Softening
008	Sedimentation, Filtration, & Softening
009	Demineralization
010	Chlorination
011	Coagulation
012	Coagulation & Filtration
013	Aeration
014	Deaeration
015	Oil Removal
016	Corrosion Inhibition
017	Scale Inhibition
018	Algae Control
019	Neutralization
020	Sedimentation, Filtration, & Chlorination
021	Sedimentation & Chlorination
022	Filtration & Chlorination
023	Color Removal
024	Activated Carbon Filtration
025	Iron & Manganese Removal

CARD 5 ☐ ☐ ☐ ☐ PROCESS WATER QUALITY REQUIREMENTS CODES
74 75 76 77

1	USPHS Drinking Water Standards
2	Any Available Water
3	No Color
4	Low Turbidity
5	Low Hardness
6	Deionized Water
7	Controlled Temperature

CARD 6 ☐ CODES FOR "OTHER" MATERIALS IN WASTE STREAMS
76

1	Taste and Odor Compounds
2	Color
3	Turbidity
4	Heavy Metals
5	Toxic Compounds
6	Residual Process Materials
7	Inorganic Chemicals
8	Organic Chemicals
9	Treatment Chemicals

CARD 7 ☐ UNIT TREATMENT CODES
31 45

001	None
002	Sedimentation Basin
003	Filtration
004	Sedimentation & Filtration
005	Softening
006	Sedimentation & Softening
007	Filtration & Softening
008	Sedimentation, Filtration, & Softening
009	Demineralization
010	Chlorination
011	Coagulation
012	Coagulation & Filtration
013	Aeration
014	Deaeration
015	Oil Removal
016	Corrosion Inhibition
017	Scale Inhibition
018	Algae Control
019	Neutralization
020	Sedimentation, Filtration, & Chlorination
021	Sedimentation & Chlorination
022	Iron Removal Filter
023	Color Removal
024	Activated Carbon Filtration
025	Iron & Manganese Removal
026	Equalization
027	Screening
028	Pre-Aeration

029	Flotation
030	Oil Separators
031	Primary Chemical Coagulation
032	Chemical Treatment
033	Nutrient Addition
034	Stabilization Basins
035	Trickling Filter
036	Activated Sludge
037	Aerated Lagoon
038	Dentrification
039	Aerobic or Anaerobic Digestion of Solids
040	Thickening
041	Lagooning or Drying Bed
042	Centrifugation
043	Vacuum Filtration
044	Dry Combustion
045	Wet Combustion
046	Land Disposal
047	Biological Sedimentation
048	Final Chemical Coagulation & Sedimentation
049	Sand Filtration
050	Diatomite Filtration
051	Chlorination
052	Evaporation
053	Freezing
054	Distillation
055	Eutectic Freezing
056	Adsorption
057	Electrodialysis
058	Ion Exchange
059	Solvent Extraction
060	Reverse Osmosis
061	Foaming
062	Electrochemical Treatment
063	Deepwell Disposal
064	Ocean Discharge
065	Chain Type Scale Scrapers
066	De-Phenolizer
067	Contract Hauling
070	Cooling Towers
071	Collection System

CARD 7 ☐ ☐ ☐ SIZE AND/OR LOADING CODES
53 57 61

1	Acres Plant Area	5	Depth in Feet
2	Square Feet Plant Area	6	Diameter in Feet
3	Cubic Feet Plant Volume	7	Overflow Rate, Ft/Min
4	Height in Feet	8	Retention Time, Min

9	LB/LB MLSS
A	Sedimentation Index, Min
B	$Lb/Ft^3/Day$
C	$Lb/Ft^2/Day$
D	$Gal/Ft^2/Day$
E	$Gal/Ft^3/Day$

CARD 8 ☐☐☐☐ CODES FOR SLUDGE DESCRIPTIONS
28 29 30 31

0001	Water Treatment Sludge
0002	Thickener Underflow
0003	Primary Sludge
0004	Final Clarifier Sludge, Activated Sludge
0005	Digestor Sludge
0006	Final Clarifier Sludge, Trickling Filter
0007	Filter Backwash
0008	Lime Neutralization Sludge
0009	Chemical Treatment Sludge

CARD 8 ☐☐☐☐ CODES FOR SLUDGE TREATMENT
32 33 34 35

0001	Thickening
0002	Filtration
0003	Lagooning
0004	Elutriation
0005	Digestor Sludge
0006	Centrifuging
0007	Digestion
0008	Wet Air Oxidation
0009	Flotation

CARD 8 ☐☐☐☐ CODES FOR SLUDGE DISPOSAL MEANS
36 37 38 39

0001	Incineration
0002	Contract Hauling
0003	Landfill
0004	Disposal at Sea
0005	Sinter Plant
0006	Sale
0007	Reuse in Plant

CARD 9 ☐☐☐ APERTURE CARD CODES
50 51 52

001	Treatment Practices Data Form
002	Process Flowsheets
003	Waste Treatment Flowsheets

CARD 10 ☐☐☐ CODES FOR SPECIALIZED FUNCTIONS
29 30 31

001	Corporate Head of Pollution Control
002	Plant Head of Pollution Control
003	Plant Utilities Chief
004	Plant Maintenance Chief
005	Plant Engineer
006	Plant Superintendent

007	Plant Chief Chemist	008	Corporate Officer

CARD 10 ☐☐☐ TRADE AND PROFESSION CODES
46 47 48

001	Electrician	006	Chemical Engineer
002	Instrument Technician	007	Civil Engineer
003	Pipe Fitter	008	Electrical Engineer
004	Chemist	009	Certified Waste Treatment Plant Operator
005	Sanitary Engineer		

CARD 10 ☐☐☐ CODES FOR SPECIFIC PROCESSES
74 75 76

Use the unit treatment codes listed for Card 7 ☐
31 45

DOCUMENT TO DATA CENTER__________________ by__________________ sh.____ of____
DATE NAME

REVISION TO DATA CENTER__________________ by__________________ Rev. ☐
DATE NAME

INDUSTRIAL WASTE TREATMENT PRACTICES DATA FORM

CARD 1 GENERAL INFORMATION

PLANT NO. ☐☐☐☐☐ (1 2 3 4 5) INITIAL FORM NO. ☐☐☐☐☐☐ (6 7 8 9 10 11) INITIAL? ☐ Yes ☐ No

INDUSTRY______________________________ S.I.C. NO. ☐☐☐☐ (12 13 14 15)

FIRM______________________________ PLANT______________________________

YEAR PLANT CONSTRUCTED ☐☐☐☐ (16 17 18 19) STATE__________ CODE ☐☐ (20 21)

CITY AND/OR COUNTY______________________________ CODE ☐☐☐☐☐ (22 23 24 25 26)

STATISTICAL AREA______________________________ CODE ☐☐☐ (27 28 29)

ECONOMIC AREA______________________________ CODE ☐☐ (30 31)

WATER RESOURCE REGION______________________________ CODE ☐☐ (32 33)

RECEIVING STREAM______________________________ CODE Major ☐☐ (34 35) Minor ☐☐ (36 37)

DATE OF DATA ACQUISITION Month ☐☐ (38 39) Year ☐☐ (40 41) BASE YEAR ☐☐☐☐ (42 43 44 45)

SINGLE PLANT FIRM ☐ (46) MULTIPLANT FIRM ☐ (47)

SIZE OF FIRM: GROSS SALES ($1000 PER YEAR) ☐☐☐☐☐☐☐ (48 49 50 51 52 53 54)

SUBSIDIARY OF ______________________________ ☐ (55)

SIZE OF FIRM IN THE INDUSTRY (PERCENT OF THE MARKET) ☐☐☐ (56 57 58)

SIZE OF FIRM IN THE INDUSTRY: LARGE ☐ (59) MEDIUM ☐ (60) SMALL ☐ (61)

OWNERSHIP OF FIRM: PUBLICLY TRADED STOCK ☐ (62) CLOSELY HELD ☐ (63)

PUBLICLY REGULATED FIRM ☐ (64) DEFENSE-ORIENTED ☐ (65)

REVISION DATE______________________________ REV. ☐☐ (78 79) END OF CARD 1 (80)

DOCUMENT TO DATA CENTER ________________ by ________________ sh.____ of ____
DATE NAME

REVISION TO DATA CENTER ________________ by ________________ Rev. ☐
DATE NAME

INDUSTRIAL WASTE TREATMENT PRACTICES DATA FORM

CARD 1 GENERAL INFORMATION

PLANT NO. ☐☐☐☐☐ 1 2 3 4 5 INITIAL FORM NO. ☐☐☐☐☐☐ 6 7 8 9 10 11 INITIAL? ☐ Yes ☐ No

INDUSTRY ________________________________ S.I.C. NO. ☐☐☐☐ 12 13 14 15

FIRM ________________________ PLANT ________________________

YEAR PLANT CONSTRUCTED ☐☐☐☐ 16 17 18 19 STATE ____________ CODE ☐☐ 20 21

CITY AND/OR COUNTY ________________________________ CODE ☐☐☐☐☐ 22 23 24 25 26

STATISTICAL AREA ________________________________ CODE ☐☐☐ 27 28 29

ECONOMIC AREA ________________________________ CODE ☐☐ 30 31

WATER RESOURCE REGION ________________________________ CODE ☐☐ 32 33

RECEIVING STREAM ________________________________ CODE Major ☐☐ 34 35 Minor ☐☐ 36 37

DATE OF DATA ACQUISITION Month ☐☐ 38 39 Year ☐☐ 40 41 BASE YEAR ☐☐☐☐ 42 43 44 45

SINGLE PLANT FIRM ☐ 46 MULTIPLANT FIRM ☐ 47

SIZE OF FIRM: GROSS SALES ($1000 PER YEAR) ☐☐☐☐☐☐☐ 48 49 50 51 52 53 54

SUBSIDIARY OF ________________________________ ☐ 55

SIZE OF FIRM IN THE INDUSTRY (PERCENT OF THE MARKET) ☐☐☐ 56 57 58

SIZE OF FIRM IN THE INDUSTRY: LARGE ☐ 59 MEDIUM ☐ 60 SMALL ☐ 61

OWNERSHIP OF FIRM: PUBLICLY TRADED STOCK ☐ 62 CLOSELY HELD ☐ 63

PUBLICLY REGULATED FIRM ☐ 64 DEFENSE-ORIENTED ☐ 65

REVISION DATE ________________________ REV. ☐☐ 78 79 END OF CARD 1 80

INDUSTRIAL WASTE TREATMENT PRACTICES DATA FORM

CARD 2 BASES FOR TREATMENT DECISIONS

SAME AS CARD 1 (1–11)

DATA FORM NO. ☐☐☐☐☐☐ 12 13 14 15 16 17

DATA BY ____________________ NAME CODE Person ☐☐ 18 19 Source ☐☐ 20 21 DATE Month ☐☐ 22 23 Year ☐☐ 24 25

BASIS OF TREATMENT STANDARDS:

COMMON LAW ☐ 26 STATUTE LAW ☐ 27 PUBLIC OPINION ☐ 28 WITHIN FIRM ☐ 29

COURTS: FEDERAL ☐ 30 STATE ☐ 31 LOCAL ☐ 32 ORDER ☐ 33 PRECEDENT ☐ 34

AGENCIES: FEDERAL ☐ 35 STATE ☐ 36 INTERSTATE ☐ 37 LOCAL ☐ 38

REGULATIONS ☐ 39 ORDER ☐ 40 CONFERENCE ☐ 41 HEARSAY ☐ 42

ACTION INITIATION WITHIN THE FIRM:

CORPORATE ____________________ CODE ☐☐☐ 43 44 45

PLANT ____________________ CODE ☐☐☐ 46 47 48

BASIS OF ACTION DECISION:

PUBLIC OPINION ☐ 49 LAW ☐ 50 LEGAL ACTION ☐ 51 ECONOMIC INCENTIVE ☐ 52

OTHER ____________________ CODE ☐☐☐ 53 54 55

BASIS OF TREATMENT DECISION:

LEAST COST: TOTAL ☐ 56 OPERATING ☐ 57 CAPITAL ☐ 58 ECONOMIC RETURN ☐ 59

WATER CONSERVATION ☐ 60 MINIMUM COMPLIANCE ☐ 61 ULTIMATE TREATMENT ☐ 62

OTHER ____________________ CODE ☐☐☐ 63 64 65

RESPONSIBILITY FOR ACTION DECISION:

CORPORATE ____________________ CODE ☐☐☐ 66 67 68

PLANT ____________________ CODE ☐☐☐ 69 70 71

RESPONSIBILITY FOR TREATMENT DECISION:

CORPORATE ____________________ CODE ☐☐☐ 72 73 74

PLANT ____________________ CODE ☐☐☐ 75 76 77

SAME AS CARD 1 (78–79) END OF CARD 2 80

INDUSTRIAL WASTE TREATMENT PRACTICES DATA FORM

CARD 3 PLANT PRODUCTION INFORMATION I

SAME AS CARD 2
1 17

Product	Code	Production Capacity	Amount	10^x	Unit
________	18 19 20 21	________	22 23 24	25	26
________	27 28 29 30	________	31 32 33	34	35
________	36 37 38 39	________	40 41 42	43	44
________	45 46 47 48	________	49 50 51	52	53
________	54 55 56 57	________	58 59 60	61	62
________	63 64 65 66	________	67 68 69	70	71

NUMBER OF S.I.C. REPRESENTED ABOVE ________ 72 73

PRODUCTION SCHEDULE ________ HRS. PER MO. 74 75 76

REMARKS:

NO. OF CARDS 3 77

SAME AS CARD 2 78 79

END OF CARD 3 80

INDUSTRIAL WASTE TREATMENT PRACTICES DATA FORM

CARD 4 PLANT PRODUCTION INFORMATION II

SAME AS CARD 3
1 17

PRINCIPAL WASTE-PRODUCING PRODUCTION PROCESSES:

____________	Code ☐☐☐☐ 18 19 20 21	____________	Code ☐☐☐☐ 22 23 24 25
____________	Code ☐☐☐☐ 26 27 28 29	____________	Code ☐☐☐☐ 30 31 32 33
____________	Code ☐☐☐☐ 34 35 36 37	____________	Code ☐☐☐☐ 38 39 40 41

SIZE OF PLANT:

EMPLOYMENT ☐☐☐ 42 43 44 10^x ☐ 45 VALUE ADDED ($/YR.) ☐☐☐ 46 47 48 10^x ☐ 49

PLANT AREA (Acres) ☐☐☐☐ 50 51 52 53 PRODUCTION____________ Amount ☐☐☐ 54 55 56 x ☐ 57 Unit ☐ 58

SIZE IN INDUSTRY: SMALL ☐ 59 MEDIUM ☐ 60 LARGE ☐ 61

AGE OF PLANT:

AGE IN YEARS ☐☐ 62 63 YEARS SINCE MAJOR MODIFICATION ☐☐ 64 65

LEVEL OF TECHNOLOGY:

OLD ☐ 66 AVERAGE ☐ 67 ADVANCED ☐ 68 TYPICAL ☐ 69 UNIQUE ☐ 70

RAW MATERIALS USED:

______________________________	Code ☐☐ 71 72
______________________________	Code ☐☐ 73 74
______________________________	Code ☐☐ 75 76

NO. OF CARDS 4 ☐ 77 SAME AS CARD 3 78 79 END OF CARD 4 80

INDUSTRIAL WASTE TREATMENT PRACTICES DATA FORM

CARD 5 WATER USES

SAME AS CARD 4
1 17

WATER USE IN PLANT:

PRIMARY PURPOSE	MAJOR SOURCE	COST ($¢$/1000 GAL. USED) TOTAL	TREATMENT	PRINCIPLE TREATMENT	USE (10^4GAL.)
TOTAL COOLING	Code ☐☐☐ 18 19 20	☐☐.☐ 21 22 23	☐☐.☐ 24 25 26	Code ☐☐☐ 27 28 29	☐☐☐ 30 31 32
TOTAL PROCESS	Code ☐☐☐ 33 34 35	☐☐.☐ 36 37 38	☐☐.☐ 39 40 41	Code ☐☐☐ 42 43 44	☐☐☐ 45 46 47
TOTAL OTHER	Code ☐☐☐ 48 49 50	☐☐.☐ 51 52 53	☐☐.☐ 54 55 56	Code ☐☐☐ 57 58 59	☐☐☐ 60 61 62

TOTAL WATER INTAKE ____ ☐☐☐ 63 64 65 10^x ☐ 66

TOTAL WATER USE ____ ☐☐☐ 67 68 69 10^x ☐ 70

PROCESS WATER QUALITY:

COMPLETELY SATISFACTORY ☐ 71 MARGINAL ☐ 72 UNSATISFACTORY ☐ 73

PROCESS WATER QUALITY REQUIREMENTS:

CODES ☐ 74 ☐ 75 ☐ 76 ☐ 77

SAME AS CARD 4
78 79

END OF CARD 5
80

INDUSTRIAL WASTE TREATMENT PRACTICES DATA FORM

CARD 6 CHARACTERISTICS OF WASTE STREAMS

SAME AS CARD 5
1 11

WASTE STREAM NO. ☐☐ 18 19 OF ☐☐ 20 21 WASTE STREAMS IN PLANT

TOTAL PLANT EFFLUENT CALCULATED AS WEIGHTED AVERAGE ☐ 22

FLOW __________ gpd ☐☐☐☐ 23 24 25 26 10^x ☐ 27

1. OIL __________ mg/l ☐☐☐☐ 28 29 30 31
2. BIOCHEMICAL OXYGEN DEMAND __________ mg/l ☐☐☐☐ 32 33 34 35
3. CHEMICAL OXYGEN DEMAND __________ mg/l ☐☐☐☐ 36 37 38 39
4. TOTAL ORGANIC CARBON __________ mg/l ☐☐☐☐ 40 41 42 43
5. SUSPENDED SOLIDS __________ mg/l ☐☐☐☐ 44 45 46 47
6. TEMPERATURE __________ °F ☐☐☐ 48 49 50
7. ALKALINITY __________ mg/l ☐☐☐☐ 51 52 53 54
8. ACIDITY __________ mg/l ☐☐☐☐ 55 56 57 58
9. TOTAL DISSOLVED SOLIDS __________ mg/l ☐☐☐☐ 59 60 61 62
10. NITROGEN __________ mg/l ☐☐☐☐ 63 64 65 66
11. PHOSPHOROUS __________ mg/l ☐☐☐☐ 67 68 69 70
12. OTHERS __________ mg/l ☐☐☐ 71 72 73 ± ☐ 74 10^x ☐ 75 CODE ☐ 76

REMARKS: __________

NO. OF CARDS 6 ☐ 77 SAME AS CARD 5 78 79 END OF CARD 6 80

INDUSTRIAL WASTE TREATMENT PRACTICES DATA FORM

CARD 7 WASTE TREATMENT AND/OR REDUCTION PRACTICES

SAME AS CARD 6
1 17

PRACTICE NO. ☐☐ 18 19 OF ☐☐ 20 21 PRACTICES IN USE IN PLANT

PRACTICE INSTITUTED IN CONNECTION WITH ABATEMENT OF POLLUTION FROM WASTE STREAM NOS: ☐☐ 22 23 ☐☐ 24 25 ☐☐ 26 27 ☐☐ 28 29

DATA ON THIS CARD IS FOR A COMPLETE TREATMENT PLANT__________ ☐ 30

1. UNIT TREATMENT__________ ☐☐☐ 31 32 33

2. UNIT TREATMENT__________ ☐☐☐ 34 35 36

3. UNIT TREATMENT__________ ☐☐☐ 37 38 39

4. UNIT TREATMENT__________ ☐☐☐ 40 41 42

5. UNIT TREATMENT__________ ☐☐☐ 43 44 45

INSTALLATION DATES: INITIAL, 19 ☐☐ 46 47 LAST MODIFIED, 19 ☐☐ 48 49

SIZE AND/OR LOADINGS:

__________ ☐☐☐ 50 51 52 Unit ☐ 53

__________ ☐☐☐ 54 55 56 Unit ☐ 57

__________ ☐☐☐ 58 59 60 Unit ☐ 61

CAPITAL COST__________ $ ☐☐☐ 62 63 64 10^x ☐ 65

LAND VALUE__________ $ ☐☐☐ 66 67 68 10^x ☐ 69

OPERATING COSTS__________ $/YR. ☐☐☐ 70 71 72 10^x ☐ 73

EFFICIENCY, % ☐☐ 74 75 ON BASIS OF CODE ☐ 76

NO. OF CARDS 7 ☐ 77 SAME AS CARD 6 78 79 END OF CARD 7 80

INDUSTRIAL WASTE TREATMENT PRACTICES DATA FORM

CARD 8 CHARACTERISTICS OF SLUDGES

SAME AS CARD 7 1 17

SLUDGE SOURCE NO. ☐☐ 18 19 OF ☐☐ 20 21 SLUDGE SOURCES IN PLANT

TOTAL OF SLUDGES IN PLANT ☐ 22 CALCULATED AS AN AVERAGE

QUANTITY LBS. PER DAY ☐☐☐☐ 23 24 25 26 x 10^x ☐ 27

DESCRIPTION OF SLUDGE:

CODE ☐☐☐☐ 28 29 30 31

TREATMENT OF SLUDGE:

CODE ☐☐☐☐ 32 33 34 35

DISPOSAL OF SLUDGE:

CODE ☐☐☐☐ 36 37 38 39

CAPITAL COST ____ $ ☐☐☐ 40 41 42 ☐ 43

LAND VALUE ____ $ ☐☐☐ 44 45 46 ☐ 47

OPERATING COSTS ____ $/YR ☐☐☐ 48 49 50 ☐ 51

ULTIMATE DISPOSAL ☐ 52 SATISFACTORY ☐ 53 MARGINAL ☐ 54 UNSATISFACTORY ☐ 55

NO. OF CARDS 8 ☐ 77 SAME AS CARD 7 78 79 END OF CARD 8 80

INDUSTRIAL WASTE TREATMENT PRACTICES DATA FORM

CARD 9 APERTURE CARDS

SAME AS CARD 8
1 17

FIRST CARD 9

TREATMENT PRACTICES DATA FORM
18 46

APERTURE CODE ☐ 50 51 52 NO. OF CARDS 9 ☐ 77

ADD. CARDS 8

18 46

APERTURE CODE ☐ 50 51 52 NO. OF CARDS 9 ☐ 77

18 46

APERTURE CODE ☐ 50 51 52 NO. OF CARDS 9 ☐ 77

18 46

APERTURE CODE ☐ 50 51 52 NO. OF CARDS 9 ☐ 77

18 46

APERTURE CODE ☐ 50 51 52 NO. OF CARDS 9 ☐ 77

18 46

APERTURE CODE ☐ 50 51 52 NO. OF CARDS 9 ☐ 77

ALL CARDS 9

SAME AS CARD 8
78 79

END OF CARD 9
80

INDUSTRIAL WASTE TREATMENT PRACTICES DATA FORM

CARD 10 MANPOWER UTILIZATION IN WASTE TREATMENT

SAME AS CARD 9 (1–17)

FUNCTION:

ADMINISTRATION ☐ 18 ANALYSIS ☐ 19 OPERATION ☐ 20 MAINTENANCE ☐ 21
SUPERVISION ☐ 22 OPERATOR ☐ 23 TECHNICIAN ☐ 24 LABORER ☐ 25
ENGINEERING: PROCESS DESIGN ☐ 26 PLANT DESIGN ☐ 27 CONSULTANT ☐ 28
OTHER__________ CODE ☐☐☐ 29 30 31

EDUCATION AND/OR EXPERIENCE:

COLLEGE: B.S. ☐ 32 M.S. ☐ 33 PH.D. ☐ 34 1 YR. ☐ 35 2 YRS. ☐ 36
3 YRS. ☐ 37 JR. COLLEGE ☐ 38 HIGH SCHOOL ☐ 39 TECHNICAL SCHOOL ☐ 40
GRADE SCHOOL ☐ 41 YEARS WORKING EXPERIENCE _____ ☐☐ 42 43
YRS. IN SPECIALTY_____ ☐☐ 44 45 TRADE OR PROFESSION_____ CODE ☐☐☐ 46 47 48

WORK LEVELS AND COSTS:

NO. OF PERSONS_____ ☐☐ 49 50 MAN-HOURS PER MONTH_____ ☐☐☐☐ 51 52 53 54
COSTS PER MAN-HOUR: WAGES____ $ ☐☐ 55 56 ☐☐ 57 58 TOTAL____ $ ☐☐ 59 60 ☐☐ 61 62

EMPLOYMENT STATUS:

FULL-TIME EMPLOYEE ☐ 63 PART-TIME EMPLOYEE ☐ 64 OUTSIDE________ ☐ 65
% OF EMPLOYED TIME DEVOTED TO WASTE TREATMENT________ ☐☐ 66 67 %
UNION MEMBER ☐ 68 EXEMPT EMPLOYEE ☐ 69 NON-EXEMPT EMPLOYEE ☐ 70

WORK AREA:

COMPANY GENERAL ☐ 71 PLANT GENERAL ☐ 72 WASTE TREATMENT PLANT ☐ 73
SPECIFIC PROCESS__________ CODE ☐☐☐ 74 75 76

REMARKS:

____

____

____

NO. OF CARDS 10 ☐ 77 SAME AS CARD 9 (78–79) END OF CARD 10 (80)

APPENDIX B

INORGANIC CHEMICAL INDUSTRY SURVEY DATA

TABLE I

Plant Number	Critical Pollutant	Efficiency	Capital Cost Per 1000 GPD	Operating Cost Per 1000 GPD	Capital Cost Per Ton/Year	Operating Cost Per Ton/Year	Wastewater GPD/Ton/Year
00013	SO_4	-	-	-	-	-	-
00016	Acidity	99	1736.11	-	2.66	-	1.53
00017	Acidity	99	2083.33	-	3.62	-	1.74
00018	-	-	-	-	-	-	18.33
00026	Acidity	99.5	1666.67	300.00	57.80	10.40	34.68
00027	-	-	6.92	1.04	1.28	0.19	185.70
00030	SS	98	-	-	-	-	336.00
00033	Cl	-	-	-	-	-	7.21
00034	SS	-	260.41	-	2.17	-	8.34
00037	Cl	-	-	-	-	-	7.22
00040	Oil	73	1.06	0.10	22.00	2.00	20736.00
00042	-	-	1.29	1.28	1.42	0.21	166.66
00050	Temp.	-	411.37	140.27	4.15	1.42	10.09
00051	SS	95	20.83	-	1.74	-	83.33
00052	SS	95	83.33	5.55	8.82	5.88	105.88
00053	SS	-	1500.00	600.00	1.44	0.58	0.96
00054	BOD	90	152.17	1.04	0.44	<0.01	2.90
00055	BOD	45	583.33	166.66	87.50	25.00	150.00
00056	SS	99.8	116.66	36.66	7.00	2.20	60.00
00057	-	-	12.00	1.00	6.00	0.50	500.00
00058	-	0	0.00	0.00	0.00	0.00	40000.00
00059	SS	90	5.00	2.50	10.00	5.00	2000.00
00060	BOD	50	387.10	32.26	0.41	0.03	1.07
00061	-	99	307.69	116.92	0.31	0.12	1.00
00062	-	0	0.00	0.00	0.00	0.00	42.42
00063	BOD	70	1.67	0.35	0.01	<0.01	6.48
00064	Acidity	-	-	-	-	-	64.11

NOTES: The following abbreviations are used:

BOD - Biochemical Oxygen Demand
SS - Suspended Solids
Cl - Chlorides
Temp. - Temperature
SO4 - Sulfates

APPENDIX C

INORGANIC CHEMICAL INDUSTRY PRODUCT PROFILES

Individual Product Profiles
Flowchart of a Standard Medium-Pressure Air-Separation Plant
Flowchart for Diaphragm Caustic Soda and Chlorine Cell
Flowchart for 60% Nitric Acid from Ammonia
Typical Flowchart for Sulfur-Burning Contact Plant
Flowchart for Smokeless Powder
Flowchart for Mixing of Paint
Flowchart for Titanium Dioxide

Sources of Data:

Chemical Profiles
Oil, Paint and Drug Reporter
"Future Inorganic Chemical Growth Patterns"
R. N. Rickles, Noyes Development
Chemical Week
Bureau of the Census
TVA

SIC 2812 (ALKALIES AND CHLORINE)

Caustic Potash

Producer	Capacity [1]
Allied, Syracuse, N.Y.	30,000
Diamond, Delaware City, Del.	12,500
Diamond, Muscle Shoals, Ala.	22,000
Dow, Pittsburg, Calif.	10,000
FMC, South Charleston, W. Va.	10,000
Hooker, Niagara Falls, N.Y.	36,000
IMC, Niagara Falls, N.Y.	22,000
Monsanto, Anniston, Ala.	25,000
Monsanto, East St. Louis, Ill.	29,000
Pennsalt, Calvert City, Ky.	5,000
PPG, Corpus Christi, Tex.	5,000
PPG, New Martinsville, W. Va.	10,000
Total	216,500

[1] 1000's of tons/year (90% basis)

Production: 1969: 180,000 tons (90% basis)
1974: 216,000 tons (90% basis)

Uses: Soaps and detergents (including use as tetrapotassium pyrophosphate), potassium carbonate and other potassium chemicals.

Processes: By the electrolysis of potassium chloride.

Waste Problems: No major change is expected. See chlorine.

Caustic Soda

Producer	Capacity [1]
Alcoa	450
Allied	1,200
Diamond	2,030
Dow	7,800
FMC	850
GAF	525
Goodrich	575
Hooker	1,780

Caustic Soda (cont.)

Producer	Capacity 1/
Kaiser	600
Monsanto	350
Olin	1,870
Pennsalt	1,100
PPG Industries	2,860
Shell	275
Stauffer	913
Vulcan	330
Weyerhaeuser	300
Wyandotte	1,870
Others	1,070
Total	26,748

1/ tons/day

Production: 1969: 8,500,000 tons/year
1974: 11,500,000 tons/year

Uses: Chemicals, pulp and paper, aluminum, rayon, textiles, petroleum refining, soap and detergents, cellophane.

Processes: Caustic soda is manufactured primarily from salt in electrolytic cells. A full discussion is included under chlorine.

Waste Problems: See chlorine.

Chlorine

Producer	Capacity 1/
Alcoa	415
Allied	1,100
Diamond	1,850
Dow	7,050
DuPont	180
Ethyl	625
FMC	765
Frontier	415
GAF	475
Goodrich	520
Hooker	1,800

Chlorine (cont.)

Producer	Capacity [1]
IMC	180
Kaiser	500
Monsanto	310
Olin	1,700
Pennsalt	1,000
PPG Industries	2,600
Shell	200
Stauffer	700
Vulcan	300
Wyandotte	1,700
Other	1,300
Total	25,685

[1] tons/day

Production: 1969: 8.6 million tons/year
1974: 12.0 million tons/year

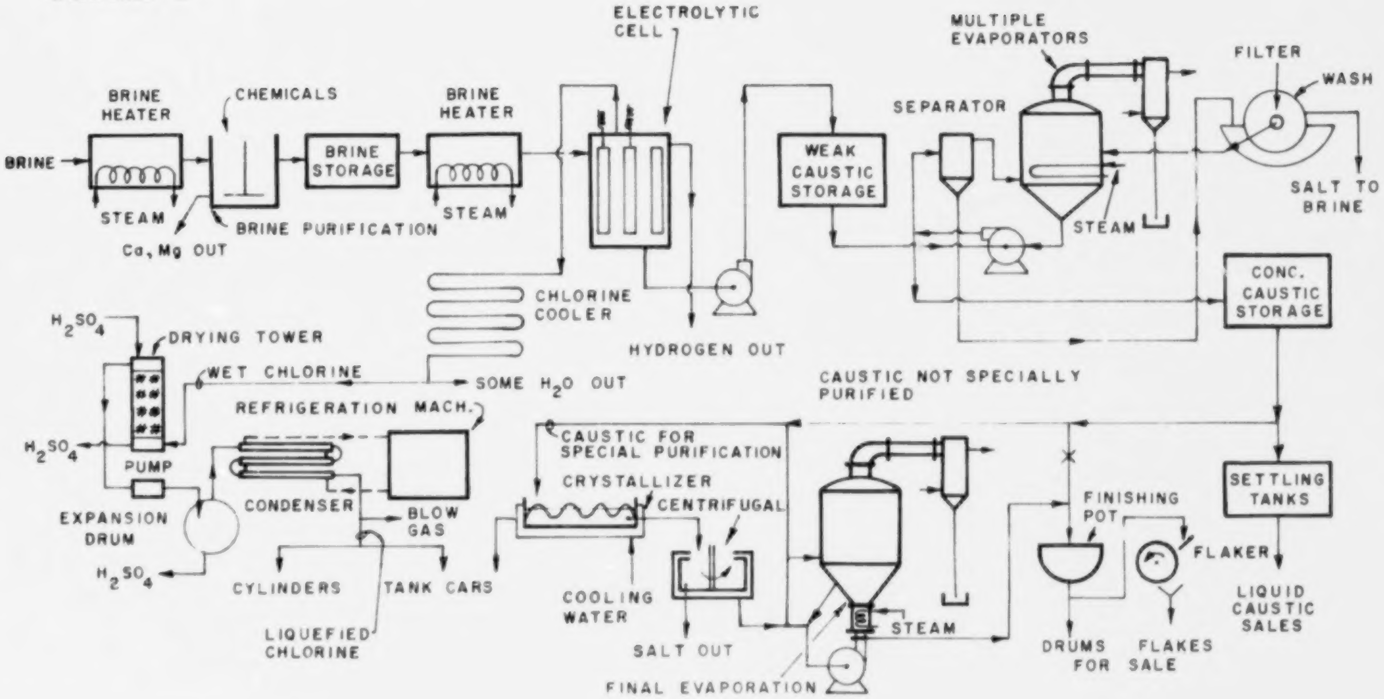
Uses: Organic chemicals, inorganic chemicals, paper industry, cyclic intermediates, sanitation, antifreeze, chlorofluoro carbons, plastics.

Processes: Chlorine and caustic soda are produced by the electrolysis of brine. As an alternative, caustic potash may be produced by the electrolysis of potash. Other sources of chlorine are from the manufacture of hydrochloric acid and sodium. Neither method is important.

Two basic methods are involved. The production is divided between the diaphragm and mercury cells and there is no expected change in the distribution. In a typical diaphragm cell, the nearly saturated brine solution at 60-70°C is fed to the anolyte which flows through the diaphragm to the catholyte where the caustic is formed. Chlorine is formed at the anode.

In the mercury cell, mercury flowing along the bottom of a steel trough forms the cathode. The anodes are horizontal graphite plates. Brine at 290 gms/liter is fed to the cell. A sodium amalgam is formed with the mercury at the cathode and is decomposed external to the cell by the addition of water. Hydrogen is produced as a by-product of this latter action.

FIGURE 1


BRINE
BRINE HEATER
STEAM
CHEMICALS
Ca, Mg OUT
BRINE PURIFICATION
BRINE STORAGE
BRINE HEATER
STEAM
ELECTROLYTIC CELL
WEAK CAUSTIC STORAGE
MULTIPLE EVAPORATORS
SEPARATOR
STEAM
FILTER
WASH
SALT TO BRINE
CONC. CAUSTIC STORAGE
CHLORINE COOLER
HYDROGEN OUT
H_2SO_4
DRYING TOWER
WET CHLORINE
SOME H_2O OUT
H_2SO_4
PUMP
EXPANSION DRUM
H_2SO_4
REFRIGERATION MACH.
CONDENSER
BLOW GAS
CYLINDERS
TANK CARS
LIQUEFIED CHLORINE
CAUSTIC NOT SPECIALLY PURIFIED
CAUSTIC FOR SPECIAL PURIFICATION
CRYSTALLIZER
CENTRIFUGAL
COOLING WATER
SALT OUT
STEAM
FINAL EVAPORATION
FINISHING POT
FLAKER
SETTLING TANKS
LIQUID CAUSTIC SALES
DRUMS FOR SALE
FLAKES

FLOWCHART FOR DIAPHRAGM CAUSTIC SODA AND CHLORINE CELL

This flow chart is selectively reproduced in content and configuration from Figure 13.7 in the book by R. Norris Shreve, *Chemical Process Industries*, Third Edition, New York, Mc Graw - Hill Book Company, 1967, p. 236

Brine purification is necessary to produce a high grade caustic in the diaphragm process. Calcium, iron magnesium and sulfate ions are precipitated. In the diaphragm process, the cell liquor, containing 50% of the sodium chloride, is concentrated.

The salt precipitates and is reused following washing. Special purification of the caustic may be necessary and this usually produces considerable sludge.

It is necessary to dry the chlorine, and this is accomplished by contact with a concentrated sulfuric stream.

The mercury cell produces, without all of the major purification problems, a high purity caustic and chlorine. This eliminates the major waste problems except those arising from chlorine drying.

No significant change is expected in this process.

Waste Problems: The waste problem common to both systems is the waste sulfuric acid stream which amounts to about 1,000,000 gpd/100 tons/day of chlorine. Such a stream (1,000,000 gpd) would contain about 2000 pounds of sulfuric acid and 200 pounds of chlorine. Regeneration of this stream is quite possible by evaporation and steam stripping of the chlorine. This would permit use of the chlorine for sterilization purposes.

Other wastes arise from the discharge of waste brine as a slipstream. This may amount to 1-5% of total brine throughput. Improved brine purification techniques could reduce these practices. The waste brine could be utilized in a small mercury cell to produce chlorine or for the regeneration of ion exchange systems. The waste brine from a mercury cell contains some mercury which requires physical separation for removal. Economics usually justifies removal.

The sludges collected from the purification of brine also create a problem, and current techniques involve land disposal or discharge to a water body. No major processing changes are anticipated.

Soda Ash

Producer	Capacity 1/
Allied, Baton Rouge, La. (S)	785,000
Allied, Green River, Wyo. (N)	550,000
Allied, Syracuse, N.Y. (S)	1,000,000
American Potash, Trona, Calif. (N)	160,000
Diamond Shamrock, Painesville, O. (S)	800,000
Dow, Freeport, Tex. (S)	75,000
FMC, Green River, Wyo. (N)	1,250,000
Olin, Lake Charles, La. (S)	3,750,000
Olin, Saltville, Va. (S)	400,000
PPG, Barberton, O. (S)	600,000
PPG, Corpus Christi, Tex. (S)	240,000
Stauffer, Green River, Wyo. (N)	800,000
Stauffer, Westend, Calif. (N)	160,000
Wyandotte, Wyandotte, Mich. (S)	800,000
Total	7,995,000

1/ tons/year (S) synthetic; (N) natural

Production: 1969: 7,000,000 tons
1974: 9,000,000 tons

Uses: Glass, chemicals, pulp and paper, soap and detergents, aluminum, water treatment.

Processes: About 30% of the current production of soda ash is obtained naturally through the mining of trona (sodium sesquicarbonate). Some amount is recovered through the calcination of natural alkali brines in California. Neither technique produces significant quantities of waste. The mining operation does produce the usual solid waste problems and any brine operation produces a waste brine solution. The location of these areas makes their impact upon the environment relatively insignificant.

The Solvay process uses brine, limestone and coke or gas as the raw material. Brine is purified as previously noted (see chlorine). Ammonia is dissolved in the purified brine and this solution is carbonated with carbon dioxide produce by the decarbonation of limestone by calcining the stone mixed with coke. This produces a moist sodium bicarbonate which is calcined to soda ash. The ammonia is recovered from the filtrate (sodium bicarbonate unit) by addition of quick lime to the system. The ammonia and carbon dioxide are recovered and recycled.

The recovery of ammonia produces a waste stream (1-2000 gals/ton) which contains ammonia (2-4 kgms of $(NH_4)_2SO_4$ per ton of 58% soda ash) and substantial amounts of calcium chloride (0.3 tons/ton of 58% Na_2) and some calcium sulfate and calcium carbonate. While some calcium chloride is recovered by distillation, this practice is not sufficiently prevalent to prevent it from being a major pollution problem.

Since calcination involves dust control, there is the likelihood of a discharge containing a large concentration of suspended solids from a scrubber or where water is used for conveying fly ash.

It is expected that more natural soda ash will be utilized, but no major changes in the manufacture of soda ash by the Solvay process are anticipated.

SIC 2813 (INDUSTRIAL GASES, EXCEPT FOR ORGANIC GASES)

Nitrogen

Producers: The number of nitrogen and oxygen producing plants is quite large and capacities of either individual plants or companies are not available. These plan to be generally located in areas of high user demand.

Major producers are:

Air Products and Chemicals - 20% of market
Airco - 20% of market
Big Three Industrial Gas
Burdett Oxygen
Chemetron - National Cylinder Gas
Union Carbide - Linde Division - 40% of market

Production: 1969: 130,000 million cubic feet
1974: 370,000 million cubic feet

Uses: Chemical and drug production, steel and metal production, electronics, aerospace, cryogenics.

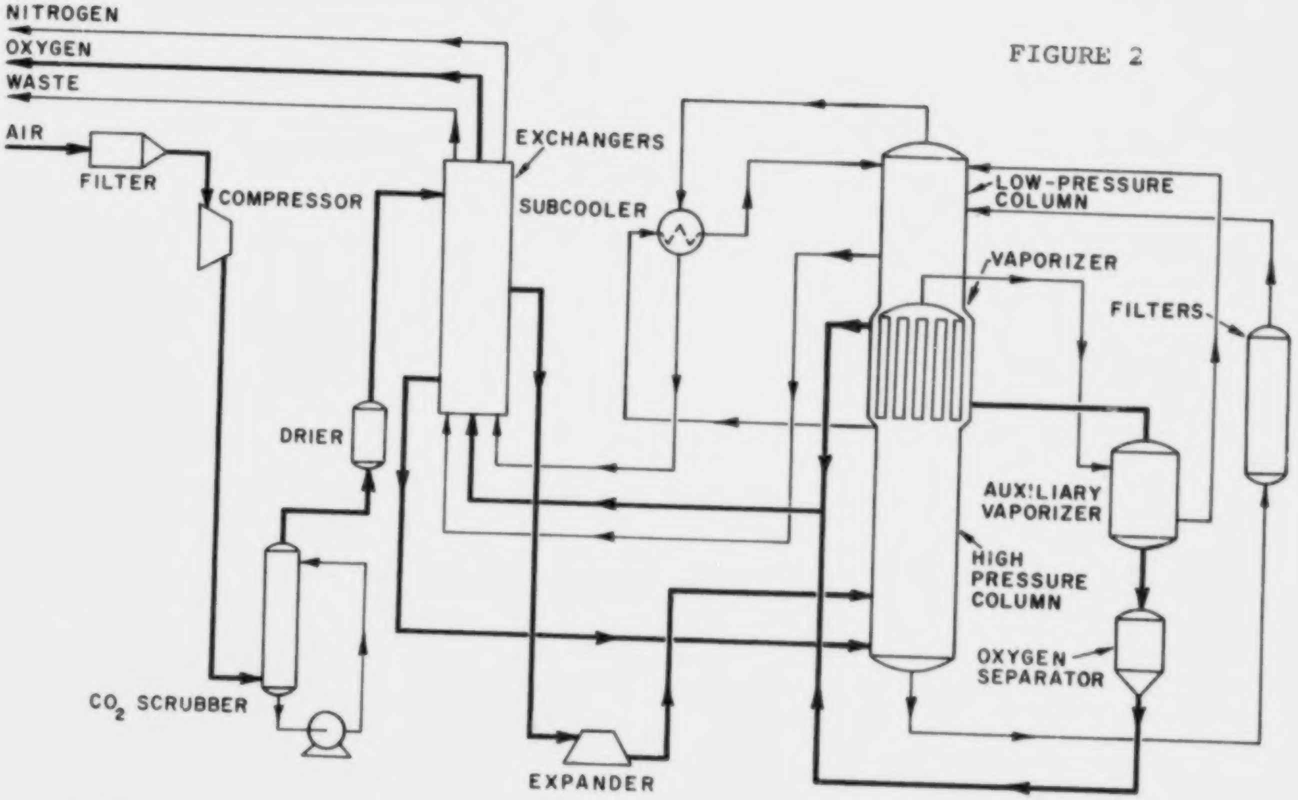
Processes: Both oxygen and nitrogen are produced primarily through the medium pressure liquification and rectification of air. The process can produce a variety of products including high purity oxygen and nitrogen and low purity oxygen. The process naturally has many variations, but it is expected that there will be no substantial changes in the method of production.

Waste Problems: The major problem associated with this process is related to the discharge, with the cooling waters, of waste compressor oils. The quantity of such oils may vary greatly from plant to plant depending on compressor type, size, and age. In-plant control is not only possible, but feasible. This is best done by skimming in the sumps.

Oxygen

Producers: See nitrogen.

FIGURE 2


NITROGEN
OXYGEN
WASTE
AIR
FILTER
COMPRESSOR
EXCHANGERS
SUBCOOLER
DRIER
CO_2 SCRUBBER
EXPANDER
LOW-PRESSURE COLUMN
VAPORIZER
FILTERS
AUXILIARY VAPORIZER
HIGH PRESSURE COLUMN
OXYGEN SEPARATOR

FLOWCHART OF A STANDARD MEDIUM-PRESSURE AIR-SEPARATION PLANT

This flow chart is selectively reproduced in content and configuration from Figure 7.7 in the book by R. Norris Shreve, *Chemical Process Industries*, Third Edition, New York, Mc Graw-Hill Book Company, 1967, p. 109

Production: High Purity (99.5-100%)
1969: 260,000 million cubic feet
1974: 520,000 million cubic feet

Low Purity
1969: 1,900,000 tons
1974: 3,800,000 tons

Uses: Chemical production, steel production, medical.

Processes: See nitrogen.

Waste Problems: See nitrogen.

SIC 2816 (INORGANIC PIGMENTS)

Barites

Producers: Produced by:
Chemical Products Corporation, Cartersville, Ga.
Chicago Copper and Chemical Corporation, Blue Island, Ill.
The Great Western Sugar Corporation, Johnstown, Colo.
Holland-Suco Color Corporation, Huntington, W. Va.
FMC, Modesto, Calif.
Mallinckrodt Chemical, St. Louis, Mo.
Ozark Smelting and Mining, Coffeyville, Kan.
PPG, New Martinsville, W. Va.

Capacities are not available.

Production: 1969: 950,000 tons
1974: 1,300,000 tons

Uses: White pigment.

Processes: Barites is recovered as a mineral which may be converted to a soluble salt, such as the chloride or the sulfide, by thermal reduction. The sulfate is then produced by the addition of a sulfate such as sodium sulfate. The resulting filtrate is a solution of the resulting chloride (usually sodium) on an equivalent mole basis. Thus, the discharge will be a brine solution. No major process change may be expected in the near future and no process improvement is considered likely.

Calcium Carbonate

Producers: Produced by:
Allied, Baton Rouge, La.
Allied, Green River, Wyo.
Allied, Syracuse, N.Y.
American Potash, Trona, Calif.
Diamond Shamrock, Painesville, O.
Dow, Freeport, Tex.
FMC, Green River, Wyo.

Olin, Lake Charles, La.
Olin, Saltville, Va.
PPG, Barberton, O.
PPG, Corpus Christi, Tex.
Stauffer, Green River, Wyo.
Stauffer, Westend, Calif.
Wyandotte, Wyandotte, Mich.

Capacities are not available.

Production: 1969: 180,000 tons (estimated)
1974: 240,000 tons

Uses: Pigment, filler, neutralization, soaps, abrasives, agriculture.

Processes: Whiting is used as a filler and pigment. It is prepared by wet grinding and levigating natural chalk. This process produces a waste which contains large amounts of suspended solids. Artificial whiting arises through the reaction of calcium chloride with sodium carbonate forming a milk of lime suspension. The filtrate from this suspension is high in suspended solids. Use of polyelectrolytes will increase recovery of this product.

Iron Oxide Pigments

Producers: Not available

Production:

1969:	Natural	Brown Iron Oxides		13,000 tons
		Umbers		5,000 tons
		Red Iron Oxides		35,000 tons
		Sienna		1,000 tons
		Yellow Ocher		5,000 tons
		Sienna		1,000 tons
			Subtotal	60,000 tons
	Manufactured	Black		4,000 tons
		Brown		5,000 tons
		Red		32,000 tons
		Yellow		24,000 tons
			Subtotal	65,000 tons
			Total	125,000 tons

1974: 160,000 tons

Processes and Waste Problems: These products are made in dry thermal processes or are produced from natural clays, etc. Therefore, except for waste slurries and equipment washouts, no serious waste problems exist. The discharge of highly colored turbid solutions from clay-mining sites is most serious locally.

Titanium Dioxide

Producer	Capacity 1/
American Potash, Hamilton, Miss. (C)	30,000
Cabot, Ashtabula, O. (C)	20,000
Cyanamid, Piney River, Va. (S)	18,000
Cyanamid, Savannah, Ga. (C,S)	92,000
DuPont, Antioch, Calif. (C)	27,000
DuPont, Baltimore, Md. (S)	40,000
DuPont, Edge Moor, Del. (C,S)	100,000
DuPont, New Johnsonville, Tenn. (C)	68,000
Glidden, Baltimore, Md. (S)	56,000
National Lead, Sayreville, N. J. (C,S)	173,000
National Lead, St. Louis, Mo. (S)	108,000
New Jersey Zinc, Gloucester City, N. J. (S)	46,000
PPG, Natrium, W. Va. (C)	18,000
S. Williams	25,000
Total	821,000

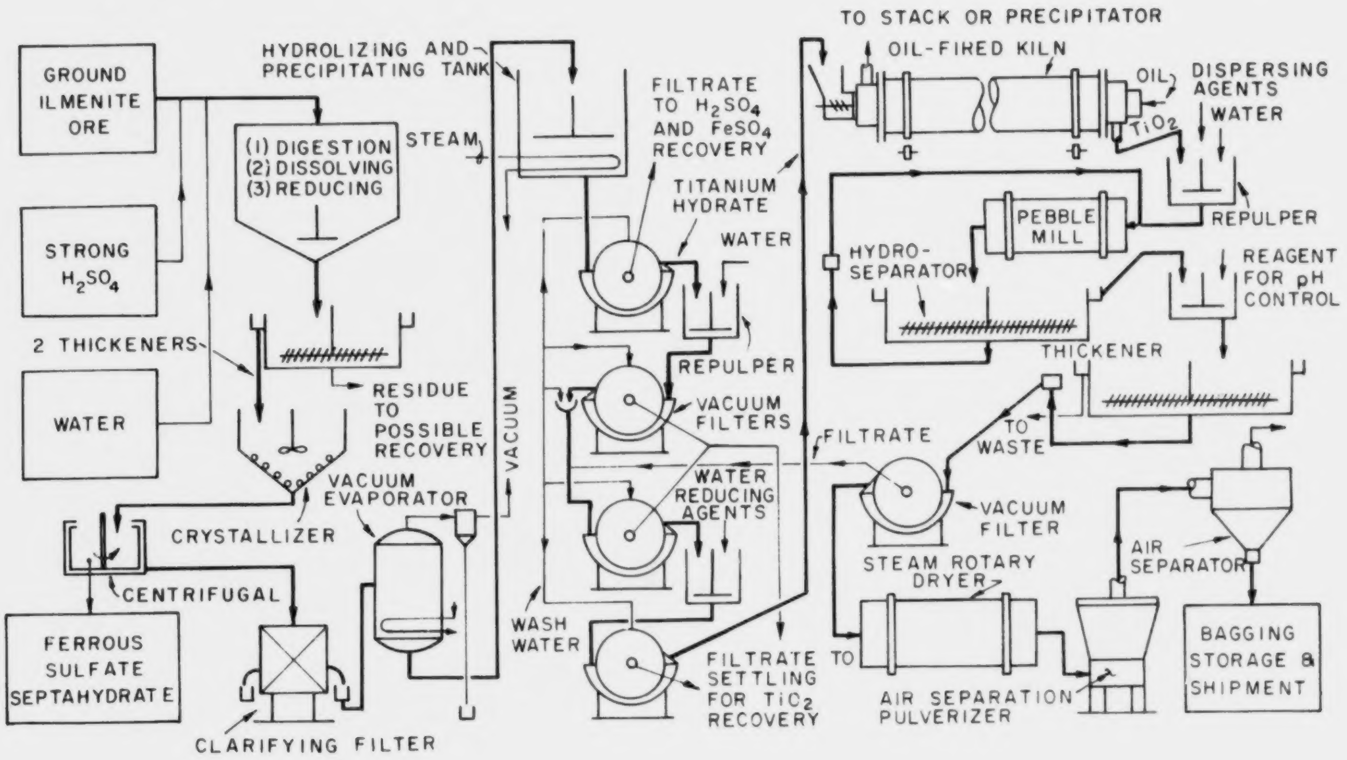
1/ tons/year (C) chloride process; (S) sulfate process

Production: 1969: 650,000 tons
1974: 800,000 tons

Uses: Varnish and lacquer, paint, floor coverings, rubber, coated fabrics, printing ink.

Processes: Titanium dioxide is produced by either of two processes. The older process is the digestion of ilmenite ore in sulfuric acid. The heat of the reaction evaporates the water. Water is added dissolving the titanium and iron sulfates. The ferric ions are reduced with scrap and the solution is clarified. Fifty percent of the iron is re-

FIGURE 3

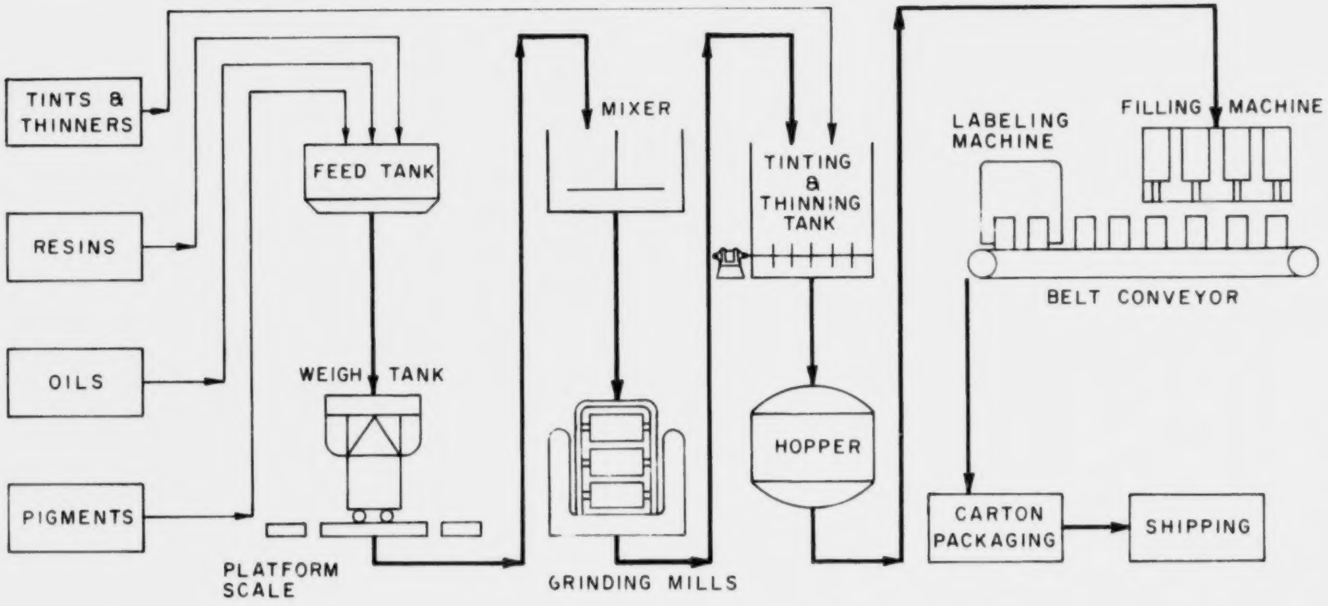


TO STACK OR PRECIPITATOR
GROUND ILMENITE ORE
STRONG H_2SO_4
WATER
2 THICKENERS
HYDROLIZING AND PRECIPITATING TANK
(1) DIGESTION
(2) DISSOLVING
(3) REDUCING
STEAM
RESIDUE TO POSSIBLE RECOVERY
VACUUM
VACUUM EVAPORATOR
CRYSTALLIZER
CENTRIFUGAL
FERROUS SULFATE SEPTAHYDRATE
CLARIFYING FILTER
FILTRATE TO H_2SO_4 AND $FeSO_4$ RECOVERY
TITANIUM HYDRATE
WATER
REPULPER
VACUUM FILTERS
WATER
REDUCING AGENTS
WASH WATER
FILTRATE SETTLING FOR TiO_2 RECOVERY
OIL-FIRED KILN
OIL
TiO_2
DISPERSING AGENTS
WATER
REPULPER
PEBBLE MILL
HYDRO-SEPARATOR
REAGENT FOR pH CONTROL
THICKENER
FILTRATE
TO WASTE
VACUUM FILTER
STEAM ROTARY DRYER
TO
AIR SEPARATION PULVERIZER
AIR SEPARATOR
BAGGING STORAGE & SHIPMENT

FLOWCHART FOR TITANIUM DIOXIDE

This flow chart is selectively reproduced in content and configuration from Figure 24.9 in the book by R. Norris Shreve, *Chemical Process Industries*, Third Edition, New York, Mc Graw-Hill Book Company, 1967, p. 438

FIGURE 4


TINTS &
THINNERS
RESINS
OILS
PIGMENTS
FEED TANK
WEIGH TANK
PLATFORM
SCALE
MIXER
GRINDING MILLS
TINTING
&
THINNING
TANK
HOPPER
LABELING
MACHINE
FILLING MACHINE
BELT CONVEYOR
CARTON
PACKAGING
SHIPPING

FLOWCHART FOR MIXING OF PAINT

This flow chart is selectively reproduced in content and configuration from Figure 24.1 in the book by R. Norris Shreve, *Chemical Process Industries*, Third Edition, New York, Mc Graw - Hill Book Company, 1967, p. 428

moved by crystallization of ferrous sulfate. The titanyl sulfate is hydrolyzed and crystallized and filtered and washed.

The newer chloride process involves the oxidation in a flame of titanium chloride produced by the chlorination, in the presence of coke of rutile ore or slag. Chlorine is recovered. The chloride process is expected to become the more standard one if supplies of rutile and slag hold out.

Waste Problems: The sulfate process generates considerable quantities of wastewater effluents. The principal sources are the wash waters from the washing of the titania and the overflow from the thickeners earlier in the process. Both steps are necessary but it seems likely that some reuse of the wash waters can be provided for.

Zinc Oxide

Producers: Major producers are:
American Zinc
Eagle Picher
New Jersey Zinc
St. Joseph Lead

Capacities are not available.

Production:
1969: 195,000 tons
1974: 220,000 tons

Processes: The American process produces zinc oxide directly from ore franklinite. The ore is mixed with coal and heated. The zinc oxide is reduced to zinc which is then oxidized to zinc oxide in cyclones and bag filters without wet wastes.

The French process involves the vaporization of zinc in a retort with indirect heat and carbon monoxide gas. The zinc and carbon monoxide are oxidized to carbon dioxide and zinc oxide. The process is dry.

The Electrothermic process is similar to the American process except that the furnace is electrically heated.

Aluminum Sulfate

Producers: Allied
American Cyanamid
DuPont
Essex
Monsanto
Olin
Stauffer

Production:	
1969:	1,090,107 tons
1974:	1,250,000 tons

Uses: Water treatment, paper sizing, dye industry.

Production: Aluminum sulfate, while commonly called alum, is not a true alum. True alums are a double sulfate of aluminum or chromium and a monovalent metal or radical.

Aluminum sulfate is made by the reaction of 60 Be' sulfuric acid with bauxite following grinding. The liquor is treated by the addition of barium sulfide to remove iron and is then clarified and solidified. Production means are not likely to change in the near future.

Waste Problems: The major wastes are slurries of solids collected in the thickener decanters. These solids can easily be collected and controlled. No major change in the amount of wastes is expected.

AMMONIUM NITRATE PLANTS
UNITED STATES

Company	Location	Capacity-1966 (thousand tons)
Agway, Inc.	Olean, N.Y.	105
Allied Chemical Corp.	Geismar, La.	385
	Hopewell, Va.	400
	Omaha, Nebr.	98
	South Point, O.	235
American Cyanamid Co.	Hannibal, Mo.	140
Apache Powder Co.	Benson, Ariz.	30
Arkla Chemical	Helena, Ark.	150
Armour Agricultural Chemical Company	Cherokee, Ala.	128
	Crystal City, Mo.	111
Calumet Nitrogen Co.	Hammond, Ind.	55
Carolina Nitrogen Co.	Wilmington, N.C.	161
Central Nitrogen Co.	Terre Haute, Ind.	134
Cherokee Nitrogen Co.	Pryor, Okla.	45
Chevron Chemical Co.	Fort Madison, Iowa	70
	Kennewick, Wash.	61
	Richmond, Calif.	55
Columbia Nitrogen Co.	Augusta, Ga.	208
Cominco American, Inc.	Beatrice, Nebr.	200
Commercial Solvents Corporation	Marion, Ill.	...
	Sterlington, La.	148
Escambia Chemical Corporation	Pace, Fla.	100
Farmers Chemical Association	Tyner, Tenn.	180
Farmland Industries	Lawrence, Kans.	208
Fel-Tex, Inc.	Fremont, Nebr.	34
Gulf Oil Corp.	Henderson, Ky.	105
	Pittsburg, Kans.	360
	Vicksburg, Miss.	43
Hawkeye Chemical Co.	Clinton, Iowa	153
Hercules, Inc.	Donora, Pa.	...
	Hercules, Calif.	140
	Louisiana, Mo.	425

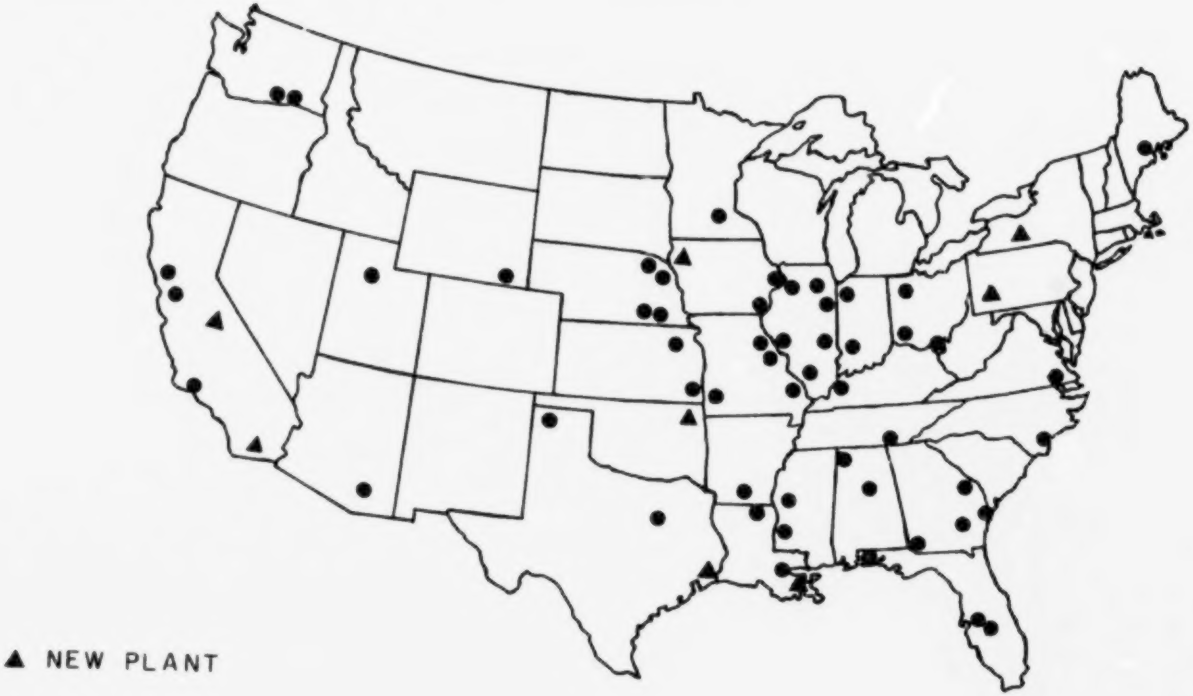
Ammonium Nitrate (cont.)

Company	Location	Capacity-1966 (thousand tons)
Illinois Nitrogen, Inc.	Marseilles, Ill.	132
Kaiser Chemical Co.	Bainbridge, Ga.	50
	North Bend, Ohio	95
	Savannah, Ga.	198
	Tampa, Fla.	54
Ketona Chemical Corp.	Ketona, Ala.	39
Mississippi Chemical Corporation	Yazoo City, Miss.	296
Mobil Chemical Co.	Beaumont, Tex.	200
Monsanto Co.	El Dorado, Ark.	280
	Luling, La.	290
Nipak, Inc.	Kerens, Tex.	56
Nitram, Inc.	Tampa, Fla.	140
Nitrin, Inc.	Cordova, Ill.	110
Northern Chemical Industries	Searsport, Maine	25
Olin Mathieson Chemical Co.	E. Alton, Ill.	50
Phillips Chemical Co.	Beatrice, Nebr.	11
	Etter, Tex.	240
	Kennewick, Wash.	20
St. Paul Ammonia Corp.	Pine Bend, Minn.	88
Smith Chemical Co.	Douglas, Ga.	...
Solar Nitrogen Chemicals Co.	Joplin, Mo.	110
	Lima, Ohio	75
Terra Chemicals International	Port Neal, Iowa	145
Texaco, Inc.	Lockport, Ill.	95
Union Oil of Calif.	Brea, Calif.	60
U.S. Industrial Chemicals Co.	Tuscola, Ill.	88
U.S. Steel Corp.	Geneva, Utah	90
Valley Nitrogen Producers	El Centro, Calif.	88
	Helm, Calif.	35
Wycon Chemical Co.	Cheyenne, Wyo.	37
	Total	7,874

Source: TVA

AMMONIUM NITRATE PLANT LOCATIONS

FIGURE 5



Production: 1969: 5,200,000 tons
1974: 6,300,000 tons

Uses: Fertilizer, explosives.

Processes: While some ammonium nitrate is manufactured by the old batch method, the vast majority is manufactured by one of a variety of continuous processes. All processes involve the direct contact of preheated ammonia and nitric acid, separation of the gaseous water, and prilling or flaking by melting. While various modifications are continuously being brought into use, no basic changes are expected.

Waste Problems: Washdown produces substantial amounts of nitrogen rich wastewaters. Additional amounts are associated with scrubber blowdowns and from cooling water. Improved plant maintenance would assist in controlling this problem.

Ammonium Sulfate

Producers: A detailed list is not available because of the large number of by-product producers, but producers include:

- Alabama By-Products
- Allied Chemical
- American Cyanamid
- Bethlehem Steel
- C. F. & I Steel
- Chevron
- Columbia Nitrogen
- DuPont
- Graver
- Inland Steel
- Interlake Steel
- Olin
- Phillips
- Shell
- Simplot
- Sinclair
- Sunray
- U. S. Pipe
- U. S. Steel

Production: 1969: 2,715,000 tons
1974: 3,000,000 tons

Uses: Fertilizer

Processes: About 35% of the production is associated with the direct reaction of ammonium salts such as the carbonate with sulfuric acid. Some is made by the use of gypsum in place of the sulfuric acid. Major discharges involve solid slurries of by-product materials.

Major amounts of ammonium sulfate are made during the recovery of ammonia from coke oven gas. About 40% of the total production is involved with the actual recovery of by-product ammonia from a variety of other processes. A plant in California is being built based on the reaction of gypsum and ammonia. To summarize, most of the ammonium sulfate produced in this country is a result of attempts to control atmospheric pollution. No change in production pattern is expected to occur.

Waste Problems: As indicated above, no major waste problem exists.

Calcium Carbide

Producer	Capacity [1/]
Airco, Calvert City, Ky.	300,000
Airco, Keokuk, Iowa	36,000
Airco, Louisville, Ky.	150,000
Midwest Carbide, Keokuk, Iowa	50,000
Midwest Carbide, Pryor, Okla.	30,000
Pacific Carbide, Portland, Ore.	20,000
Union Carbide, Ashtabula, Ohio	228,000
Union Carbide, Niagara Falls, N. Y.	210,000
Union Carbide, Portland, Ore.	32,000
Union Carbide, Sheffield, Ala.	60,000
Total	1,116,000

1/ tons/year

Production: 1969: 920,000 tons
1974: 900,000 tons

Uses: Production of acetylene.

Processes: Calcium carbide is prepared from quicklime and carbon (usually coke, petroleum coke or anthracite) at 2000-2200°C in a furnace related to the familiar arc furnace. No major process change is expected but the use of carbide-based acetylene is expected to be reduced in the future.

Waste Problems: Since the process is not a wet process, the only major discharges are associated with wastewaters used to scrub furnace and kiln effluents.

Hydrochloric Acid

Producers: Most HCl is produced as a by-product from the production of carbon tetrachloride and other chlorinated hydrocarbons, PVC, ethylene oxide, and phenol. (See "Projected Wastewater Treatment Costs in the Organic Chemicals Industry," Department of the Interior.) Major producers of anhydrous HCl are:

Detrex
Diamond Shamrock
Dow
Hooker
Montrose
Morton
Shell
Stauffer
Vulcan

Major producers of aqueous HCl are:

Allied
Arkla
Baker
Cabot
Detrex
Diamond Shamrock
Dow
DuPont
GAF
Hooker
Mobay
Monsanto
Mont
Morton
Olin
PPG
Pearsall
Pennsalt
PCA
Reichhold
Shell
Stauffer
Velsicol
Vulcan
Wyandotte

Production: 1969: 1,800,000 tons
1974: 2,200,000 tons

Uses: Oil well activation, chemical production, steel pickling, monosodium glutamate and starch hydrolysis, metal cleaning.

Processes: The major portion of HCl currently produced (85%) is a by-product of the chlorination of hydrocarbons. However, it is expected that the amount of by-product HCl available will be greatly decreased in the future for several reasons. These include:

1. The practice of oxychlorination is increasing rapidly and this, in a balanced system, can eliminate the presence of waste HCl.
2. Most vinyl chloride plants employ oxychlorination and do not produce major amounts of waste acid.
3. A new process, based on a modification of the old Deacon process, as developed by Kellogg, is expected to produce large amounts of chlorine (note impact on chlorine under #2812) and consume substantial amounts of by-product acid.

There are sufficient amounts of waste acids available so that the short term supply will not be a problem.

Three other sources of supply are as follows:

1. Direct burning of chlorine in a small excess of hydrogen. This is followed by the adsorption of HCl in water, followed by stripping to produce a high purity HCl.
2. The reaction of salt and sulfuric acid in a high temperature furnace. Sodium sulfate is formed as a by-product. Adsorption of the acid in water takes place with removal of salt and acid in a coke tower.
3. A Hargreaves-type operation which involves the reaction of salt, sulfur dioxide, oxygen and water to form sodium sulfate and acid. (This process is used by only one plant.)

Waste Problems: In the salt acid reaction, the washing out of the coke tower produces a waste stream of acid and salt. Improved furnace design would cut down on the amount of carryover.

In the salt-acid process, as in the Hargreaves reaction, a stream of weak sulfuric amounting to 50-90 lbs/ton 20° Be' hydrochloric acid is produced.

Weak hydrochloric acid is also wasted from the system.

Hydrofluoric Acid

Producer	Capacity 1/
Alcoa, Point Comfort, Tex.	25,000
Allied, Baton Rouge, La.	15,000
Allied, Geismar, La.	15,000
Allied, Nitro, W. Va.	20,000
Allied, North Claymont, Del.	25,000
Allied, Port Chicago, Calif.	12,000
DuPont, Deepwater Point, N. J.	15,000
DuPont, Strang, Tex.	50,000
Essex, Paulsboro, N. J.	11,000
Harshaw, Cleveland, Ohio	10,000
Kaiser, Gramercy, La.	15,000
Olin, Joliet, Ill.	12,000
Pennsalt, Calvert City, Ky.	18,000
Reynolds, Bauxite, Ark.	40,000
Stauffer, Houston, Tex.	18,000
Total	301,000

1/ tons/year

Production: 1969: 310,000 tons
1974: 420,000 tons

Uses: Fluorocarbons, aluminum, petroleum alkylation, stainless steel pickling, AEC work.

Processes: HF is prepared by heating, in kilns, the ore-fluorspar (CaF_2) with sulfuric acid. The gaseous HF is either absorbed in water or liquified, employing refrigeration to obtain the anhydrous product.

Waste Problems: Not significant except in washout where fluoride concentrations can be a serious problem.

Hydrogen Peroxide

Producer	Capacity [1]
Allied, Syracuse, N. Y.	4,000
DuPont, Memphis, Tenn.	25,000
FMC, Buffalo, N. Y.	6,000
FMC, South Charleston, W. Va.	8,000
FMC, Vancouver, Wash.	6,000
Pennsalt, Wyandotte, Mich.	1,750
Pittsburgh Plate, Barberton, Ohio	3,750
Shell, Norco, La.	17,000
Total	71,500

[1] tons/year

Production: 1969: 70,000 tons
1974: 100,000 tons

Uses: Textiles, paper and pulp, plasticizers, chemicals.

Processes: Hydrogen peroxide is manufactured by one electrolytic and two organic oxidation processes. Sulfuric acid is electrolyzed to peracid ($H_2S_2O_8$) which hydrolyzes to sulfuric acid and peroxide.

The organic processes center on 2-ethylanthraquinone which is oxidized to produce peroxide and recycleable quinone and isopropyl alcohol. The latter are oxidized at modest temperatures and pressures to peroxide and acetone.

Waste Problems: The electrolytic process produces a stream of dilute sulfuric acid. The organic based processes will probably produce a waste stream from the distillation column.

Lime

Producers: There are some 210 lime producing plants located wherever there are significant limestone deposits. This list is too exhaustive for display here. Refer to "Minerals Yearbook," U. S. Bureau of Mines, for a complete listing.

Production: 1969: Quicklime - 14,000,000 tons
Hydrated - 3,000,000 tons
1974: Total - 19,000,000 tons

Uses: Agriculture, chemical manufacture, pulp manufacture, tanning, steel and cement manufacture, water treatment, soap manufacturing, construction.

Processes: Thermal decarbonation of limestone or calcium carbonate sludge usually in a shaft kiln or a rotary kiln but also in a fluidized bed kiln.

Waste Problems: These generally arise if solids capture is by wet scrubbing. Conversion to a dry capture system such as bag filters would eliminate the problem.

Nitric Acid

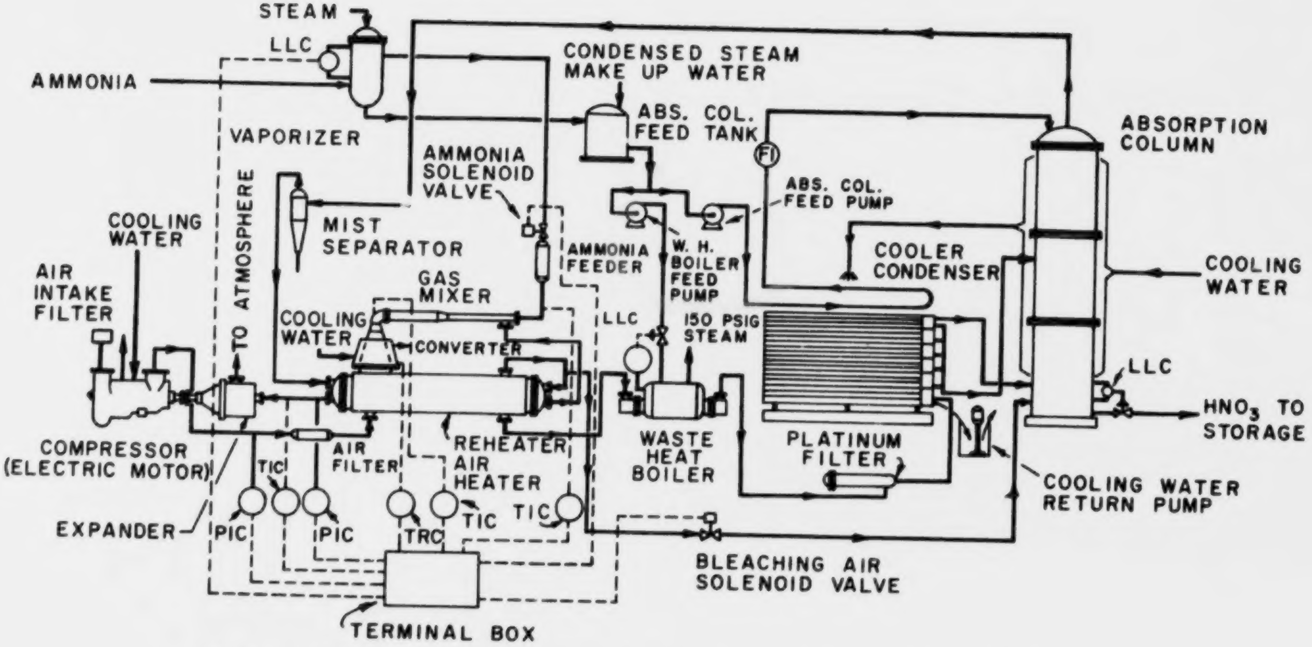
Producers:

		Estimated capacity ('68) (1,000 tons/ year)	
Company	Plant Location	Plant	Co. Total
Agway	Olean, N.Y.	60	60
Allied	Buffalo, N.Y.	25	
	Geismar, La.	200	
	Hopewell, Va.	250	
	La Platte, Nebr.	90	
	Newell, Pa.	60	
	South Point, O.	240	
			865
American Cyanamid	Bound Brook, N.J.	25	
	Hannibal, Mo.	110	
	Willow Island, W. Va.	27	
			162
Arkla	Helena, Ark.	90	90
Armour	Cherokee, Ala.	110	
	Crystal City, Mo.	100	
			210
Atlas	Joplin, Mo.	122	
	Tamaqua, Pa.	24	
			146
Celanese	Bay City, Tex.	77	77
Central Farmers	Fremont, Nebr.	31	31
Central Nitrogen	Terre Haute, Ind.	133	133

Nitric Acid (cont.)

Company	Plant Location	Estimated capacity ('68) (1,000 tons/ year) Plant	Co. Total
Cherokee	Prior, Okla.	65	65
Chevron	Ft. Madison, La.	94	309
	Kennewick, Wash.	130	
	Richmond, Calif.	85	
Collier	Brea, Calif.	47	47
Columbia Nitrogen	Augusta, Ga.	162	162
Cominco	Beatrice, Nebr.	135	135
Commercial Solvents	Marion, Ill.	50	213
	Sterlington, La.	163	
Cooperative Farm Chems.	Lawrence, Kans.	485	485
DuPont	Barksdale, Wis.	20	1,216
	Belle, W. Va.	82	
	Birmingham, Ala.	20	
	DuPont, Wash.	20	
	Gibbstown, N.J.	350	
	Louviers, Colo.	15	
	Old Hickory, Tenn.	44	
	Orange, Tex.	180	
	Victoria, Tex.	120	
	Seneca, Ill.	215	
	Wabash, Ind.	150	
El Paso	Odessa, Tex.	63	63
Escambia	Pensacola, Fla.	90	90
Farmers' Chemical	Tyner, Tenn.	170	170
Grace	Wilmington, N. C.	164	164
Gulf	Henderson, Ky.	85	451
	Pittsburg, Kans.	281	
	Vicksburg, Miss.	85	
Hawkeye	Clinton, La.	125	125
Hercules	Bessemer, Ala.	20	674
	Hercules, Calif.	65	
	Kenvil, N.J.	16	
	Louisiana, Mo.	400	
	Parling, N.J.	53	
	Donora, Pa.	120	
Illinois Nitrogen	Marseilles, Ill.	120	120

FIGURE 6


STEAM
LLC
AMMONIA
VAPORIZER
CONDENSED STEAM MAKE UP WATER
ABS. COL. FEED TANK
AMMONIA SOLENOID VALVE
ABSORPTION COLUMN
FI
ABS. COL. FEED PUMP
COOLING WATER
TO ATMOSPHERE
MIST SEPARATOR
AMMONIA FEEDER
W. H. BOILER FEED PUMP
COOLER CONDENSER
COOLING WATER
AIR INTAKE FILTER
GAS MIXER
COOLING WATER
CONVERTER
LLC
150 PSIG STEAM
LLC
HNO_3 TO STORAGE
COMPRESSOR (ELECTRIC MOTOR)
AIR FILTER
REHEATER
AIR HEATER
WASTE HEAT BOILER
PLATINUM FILTER
COOLING WATER RETURN PUMP
TIC
EXPANDER
PIC
PIC
TRC
TIC
TIC
BLEACHING AIR SOLENOID VALVE
TERMINAL BOX

FLOWCHART FOR 60% NITRIC ACID FROM AMMONIA

This flow chart is selectively reproduced in content and configuration from Figure 18.9 in the book by R. Norris Shreve, *Chemical Process Industries*, Third Edition, New York, Mc Graw - Hill Book Company, 1967, p. 318

Nitric Acid (cont.)

Company	Plant Location	Estimated capacity ('68) (1,000 tons/ year)	
		Plant	Co. Total
Kaiser	Bainbridge, Ga.	47	
	North Bend, O.	84	
	Savannah, Ga.	162	
	Tampa, Fla.	42	
			335
Ketona	Ketona, Ala.	36	36
Miscoa	Yazoo City, Miss.	388	388
Mobay	New Martinsville, W. Va.	50	50
Mobil	Beaumont, Tex.	154	154
Monsanto	El Dorado, Ark.	275	
	Luling, La.	270	
	Pensacola, Fla.	258	
			803
Nipak	Kerens, Tex.	50	50
Nitram	Tampa, Fla.	120	120
Nitrin	Cordova, Ill.	95	95
Northern Chemical Industries	Searsport, Maine	25	25
Olin Mathieson	Lake Charles, La.	95	95
Phillips Chemical	Kennewick, Wash.	43	
	Beatrice, Nebr.	9	
	Etter, Tex.	164	
	Pasadena, Tex.	13	
St. Paul Ammonia	Pine Bend, Minn.	100	100

Production: 1969: 6,140,000 tons
1974: 7,000,000 tons

Uses: Fertilizers, chemicals, photoengravings, explosives.

Processes: Nitric acid is produced by the catalytic air oxidation of ammonia. Nitric oxide is absorbed in water and oxidized. Higher strength nitric acid is produced by breaking the azeotrope with either sulfuric acid or magnesium nitrate. No significant changes are expected in the production of nitric acid.

Waste Problems: Major problems are associated with cooling water blowdown and area washdown which may contain troublesome amounts of nitric acid.

Phosphoric Acid

Producers	Location	Capacity (tons 100% P_2O_5/yr)
Allied Chemical	E. St. Louis, Ill.	36,200
	N. Claymont, Del.	36,200
	Geismar, La.	159,300
American Agricultural Chem.	Pierce, La.	216,000
American Cyanamid	Brewster, Fla.	148,800
American Potash	Trona, Calif.	Not Available
Arkla Chemical	Helena, Ark.	50,000
Armour Agricultural	Bartow, Fla.	85,000
	Ft. Meade, Fla.	188,000
Borden	Piney Point, Fla.	165,000
	Streator, Ill.	24,000
	Texas City, Tex.	60,000
Bunker Hill	Kellogg, Ida.	24,500
Central Phosphates	Plant City, Fla.	200,000
Coastal Chemical	Pascagoula, Miss.	175,900
Consumers Cooperative	Pierce, Fla.	200,000
Des Plaines Chemical	Morris, Ill.	50,000
El Paso Natural Gas	Conda, Ida.	100,000
Farmers Chemical	Joplin, Mo.	55,000
Freeport Sulfur	Uncle Sam, La.	540,000
W. R. Grace	Bartow, Fla.	415,000
	Joplin, Mo.	35,000
National Phosphate	Taft, La.	207,000
	Marseilles, Ill.	103,500
IMC	Bonnie, Fla.	500,000
New Jersey Zinc	Depue, Ill.	150,000
Nipak	Tulsa, Okla.	21,000
NW Cooperative Mills	Pine Bend, Minn.	32,000

Phosphoric Acid (cont.)

Producers	Location	Capacity (tons 100% P_2O_5/yr)
Occidental Petroleum	Hamilton Co., Fla.	207,000
Best Fertilizer	Lathrop, Calif.	17,300
Olin Mathieson	Joliet, Ill.	127,000
	Pasadena, Tex.	217,500
Phosphate Chemicals	Pasadena, Tex.	50,000
F. S. Royster Guano	Mulberry, Fla.	130,000
J. R. Simplot	Pocatello, Ida.	265,000
Mobil Chemical	Nichols, Fla.	125,000
Western Phosphates	Garfield, Utah	70,000
Swift	Agricola, Fla.	126,300
Tennessee Corp.	E. Tampa, Fla.	490,000
TGS	Aurora, N. C.	347,000
U.S. Industrial Chemicals	Tuscola, Ill.	40,000
Valley Nitrogen	Helm, Calif.	50,000
Western States Chem.	Point Chicago, Calif.	90,000
	Total	5,807,500

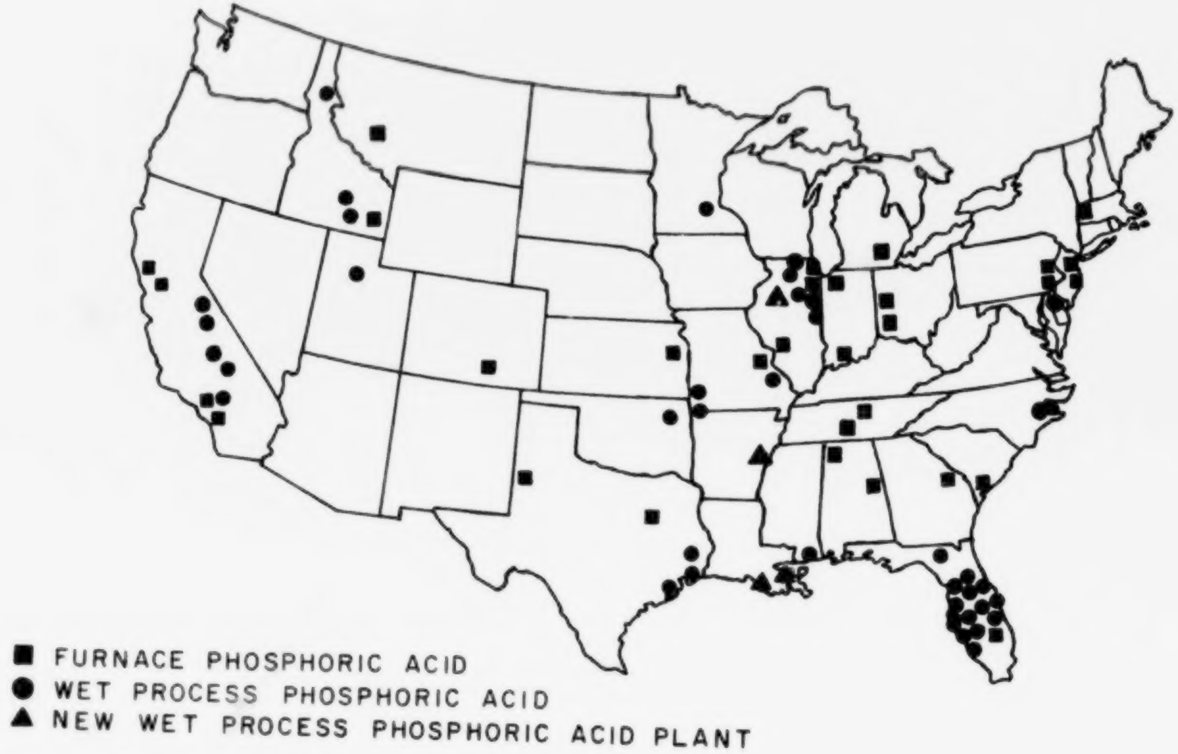
Production: 1969: 4,926,000 tons (100% P_2O_5)
1974: 5,900,000 tons (100% P_2O_5)

Uses: Fertilizer, detergents, food.

Processes: Phosphoric acid is produced by two methods. One method involves the hydrolysis of phosphorous and will be discussed under phosphorous. The most common approach is responsible for some 80% of the total production; this is from the acidulation of phosphate rock. Usually the acidulation involves the use of sulfuric acid. The acid is concentrated while the by-product, gypsum, is filtered and washed.

PHOSPHORIC ACID PLANT LOCATIONS

FIGURE 7


■ FURNACE PHOSPHORIC ACID
● WET PROCESS PHOSPHORIC ACID
▲ NEW WET PROCESS PHOSPHORIC ACID PLANT

Alternative routes involve the use of nitric or hydrochloric in place of sulfuric. This approach is not likely to make any impact on acid production.

The swing towards production of a more usable by-product in the form of the hemihydrate will have a major impact upon waste treatment. On the other hand, increasing pressure relative to air pollution will increase the removal of fluorides and thereby increase waste streams.

Waste Problems: Waste arises from at least four sources in the process. The primary source is the waste gypsum from the acidulation. This semi-solid waste may contain quantities of phosphoric and sulfuric acid. The development of techniques for utilizing the waste product should greatly reduce the magnitude of the problem.

The second source is the water from the scrubbers which contain large amounts of acid fluorides. By-product use would appear to be the answer here, as well. Increasing amounts are utilized as a source for fluoride chemicals.

This third waste source is the sludge of aluminum and iron phosphate sludge produced by the post precipitation of the acid. This may amount to 1-5% of production.

A fourth source involves the tailings from the rock beneficiation. No change in these waste sources is anticipated.

Phosphorus

Producers	Location	Capacity (tons/year)
Continental Oil	Pierce, Fla.	30,000
	El Paso, George-town, Ida.	21,000
FMC	Pocatello, Idaho	142,000
Hooker	Columbia, Tenn.	68,500
Mobil (V-C)	Charleston, S. C.	10,000
Mobil (V-C)	Mt. Pleasant, Tenn.	20,000
Mobil (V-C)	Nichols, Fla.	6,000

Phosphorus (cont.)

Producers	Location	Capacity (tons/year)
Monsanto	Columbia, Tenn.	110,000
Monsanto	Soda Springs, Idaho	120,000
Stauffer	Mt. Pleasant, Tenn.	80,000
Stauffer	Silver Bow, Mont.	30,000
Stauffer	Tarpon Springs, Fla.	12,500
TVA	Wilson Dam, Ala.	110,000
	Total	760,000

Production: 1969: 610,000 tons
1974: 740,000 tons

Uses: Sodium tripolyphosphate, phosphoric acid, other sodium phosphates, calcium phosphates, tetrapotassium pyrophosphate, sodium metaphosphate.

Processes: Phosphate rock is mixed with sand and coke, sintered and introduced into an electric furnace. After heating at elevated temperature, slag and ferrophosphorous is drawn off. Phosphorous vapor is drawn off and condensed. Phosphorous is oxidized to P_2O_5 which is cooled and hydrated, filtered and purified.

Waste Problems: A stream containing a significant amount of phosphorous (1% of production) is known as "phossy" water. The phosphorous may be settled, thickened and recycled. The filtration of the acid also produces a waste sludge of acid which causes a disposal problem. No major processing changes are anticipated.

TKPP

Producer	Location	Capacity 1/
FMC	Carteret, N. J.	10,000
FMC	Newark, Calif.	2,500
Hooker	Jeffersonville, Ind.	5,000
Mobil (V-C)	Fernald, Ohio	12,000
Monsanto	Carondelet, Mo.	15,000

TKPP (cont.)

Producer	Location	Capacity 1/
Olin	Joliet, Ill.	5,000
Stauffer	Chicago Heights, Ill.	7,500
Stauffer	South Gate, Calif.	2,500
	Total	59,500

1/ tons/year

Production: 1969: 48,500 tons
1974: 60,000 tons

Uses: Liquid detergent builder.

Processes: TKPP is prepared by the reaction of phosphoric acid and potassium carbonate to produce dipotassium-phosphate which is calcined to TKPP.

Waste Problems: Not significant.

Sodium Metal

Producers	Location	Capacity 1/
DuPont	Memphis, Tenn.	70
	Niagara Falls, N.Y.	84
Ethyl	Baton Rouge, La.	90
	Houston, Tex.	60
National Distillers	Ashtabula, Ohio	56
	Total	360

1/ million lbs/year

Production: 1969: 165,000 tons
1974: 200,000 tons

Uses: Tetraethyl and tetramethyl lead, potassium, sodium peroxide, sodium cyanide.

Processes: Electrolysis of fused sodium chloride. The crude sodium is filtered at 105-110°C.

Waste Problems: Since the process is run dry, waste problems are limited to washouts, spills and filter cake discharge.

Sodium Bicarbonate

Producer	Location	Capacity 1/
Church & Dwight	Syracuse, N. Y.	100,000
Church & Dwight	Green River, Wyo.	40,000
Diamond	Painesville, Ohio	28,000
Olin	Saltville, Va.	23,000
PPG	Barberton, Ohio	40,000
Wyandotte	Wyandotte, Mich.	30,000
	Total	261,000

1/ tons/year

Production: 1969: 205,000 tons
1974: 235,000 tons

Uses: Food, chemicals, drugs, fire extinguishant, soap and detergents, leather, textile, and paper.

Processes: Sodium bicarbonate is not made by refining the crude sodium bicarbonate from the Solvay process. A saturated solution of soda ash (natural or synthetic) is prepared and is carbonated with CO_2 in a tower. The suspension is filtered, washed, centrifuged and dried.

Waste Problems: Major problem is the blowdown of the filter cake and filter cake washups. No significant process changes are expected and no change in the nature of pollutional problems seems likely.

Sodium Bichromate

Producer	Location	Capacity 1/
Allied	Baltimore, Md.	90,000
Diamond Shamrock	Kearny, N.J.	15,000
Diamond Shamrock	Painesville, Ohio	50,000
Hercules	Glen Falls, N.Y.	16,000
Pittsburgh Plate	Corpus Christi, Tex.	35,000
	Total	206,000

1/ tons/year

Production: 1969: 150,000 tons
1974: 165,000 tons

Uses: Pigments, leather tanning, chromic acid, metal treatment, textiles and dyes.

Processes: The raw material is a chromium iron oxide containing about 50% Cr_2O_3. The ore is ground to 200 mesh, mixed with limestone and soda ash and heated to 2200°F in a strongly oxidizing atmosphere. The mass is leached with hot water to remove the soluble sodium chromate. The solution is acidified to convert the chromate to dichromate. The sodium sulfate crystallizes out and the solution is sent to crystallizers to recover the dichromate. No process changes are expected.

Waste Problems: The solution coming off the crystallizers contains about 0.1 ton of Na_2SO_4 per ton of sodium dichromate and minor amounts of sodium dichromate and chromate. Use of ion exchange and other concentrating systems could permit recovery from this system.

Sodium Chloride

Producers	Capacity 1/
Morton	6
International	4
Diamond Crystal	2.5
Leslie	1.5
Other salt companies	5
Total noncaptive capacity	19
Captive to chemical companies	22
Total salt and brine	41

1/ million tons/year

Production: 1969: 43,000,000 tons
1974: 57,000,000 tons

Uses: Production of chlorine, caustic, soda ash, other chemicals, highway use, food, feed, water conditioning.

Processes: Salt is obtained in three fashions: one by solar evaporation of sea water or western lake brines; another from well brine and a third by the mining of rock salt. It is necessary to remove calcium and magnesium chlorides, usually by undertaking evaporative concentration followed by filtration of the precipitated salts of Mg and Ca. The process may undergo some modification but major changes are not likely.

Waste Problems: Wastewater results from two sources. One is the deposits of calcium and magnesium salts which are removed in the process. This slurry can amount to 3-5% of the total process flow.

The second source is the slip stream removed to control impurities in any recycling system such as the Alberger method. Use of a concentrating or an ion control system may be effective in controlling this problem internally.

Sodium Silicate

Producer	Capacity 1/
Allied	105,000
Amerace	25,000
Chemical Products	10,000
Diamond	230,000
DuPont	150,000
Grace	65,000
Philadelphia Quartz	225,000
Philadelphia Quartz (Calif.)	35,000
Pittsburgh Plate	60,000
Proctor & Gamble	20,000
Twin Chemical	15,000
Total	940,000

1/ tons/year

Production: 1969: 640,000 tons
1974: 750,000 tons

Uses: Catalysts and silica gels, soaps and detergents, boxboard adhesives, pigments, water, paper and ore treatment.

Processes: Sodium silicates are prepared by fusing sodium carbonate and silica sand in a glass melting furnace at about 1300°C. If the product is to be sold as a solution, it is dissolved by steam injection. No process change is anticipated.

Waste Problems: None except washdown.

Sodium Sulfite

Producer	Location	Capacity 1/
Allied	El Segundo, Calif.	5,000
Allied	N. Claymont, Del.	10,000
Koppers	Petrolia, Pa.	25,000
Monsanto	Monsanto, Ill.	62,500
Reichhold	Tuscaloosa, Ala.	145,000
Stauffer	South Gate, Calif.	3,000
	Total	250,500

1/ tons/year

Production: 1969: 230,000 tons
1974: 240,000 tons

Processes: Direct contact between SO_2 and soda ash followed by boiling off of CO_2. Sesqihydrate is precipitated. Another source is as a by-product in the preparation of phenol by the fusion of sodium benzene sulfonate with caustic (See "Waste Water Treatment Costs in the Organic Chemical Industry," U. S. Department of the Interior).

Uses: Sulfite pulping, water treatment, photo grade.

Waste Problems: The waste solution contains a saturated solution of sulfite which has an immediate oxygen demand if released to the river. Additional recycling and reuse is possible and, if practiced, dumping may be eliminated.

Sodium Sulfate

Producer	Capacity 1/
Allied (B)	45,000
American Cyanamid (O)	13,000
American Enka (R)	56,000
American Potash (N)	250,000
Beaunit (R)	42,000
Climax Chemical (M)	35,000
Diamond Shamrock (B)	50,000
DuPont (M)	30,000
FMC (R)	275,000
Hercules (B,M)	25,000
Huber (O)	8,000
Industrial Rayon (R)	36,000
Koppers (O)	15,000
Lithium Corporation (O)	15,000
Monsanto (O)	35,000
Morton Chemical (M)	120,000
Ozark-Mahoning (N)	200,000
Stauffer (N,O)	200,000
U. S. Borax (O)	30,000
Miscellaneous	25,000
Total	1,505,000

1/ tons/year

B-Bichromate; O-Other; R-Rayon or Cellophane; N-Natural; M-Mannheim or Hargreaves

Production: 1969: 1,500,000 tons/year
1974: 1,800,000 tons/year

Uses: Sulfate pulping, detergents, glass.

Processes: Much of the sodium sulfate is from by-product sources discussed elsewhere. Glauber's salt ($Na_2SO_4.10H_2O$) is made by dissolving salt cake in mother liquor, adding of $CaCl_2$ and lime. The Mg, Ca and Fe are permitted to settle and the mud washed. Crystallization takes place in pans and anhydrous sodium sulfate is prepared by dehydrating Glauber's salt. No new sources or processes are anticipated.

Waste Problems: Disposal of the mud is the primary problem and in-plant control would have little impact on this problem.

Sodium Tripolyphosphate

Producer	Location	Capacity 1/
Allied	N. Claymont, Del.	30,000
AAC	Carteret, N. J.	40,000
FMC	Carteret, N. J.	150,000
FMC	Green River, Wyo.	50,000
FMC	Lawrence, Kans.	75,000
FMC	Newark, Calif.	50,000
Hooker	Adams, Mass.	25,000
Hooker	Dallas, Tex.	25,000
Hooker	Jeffersonville, Ind.	75,000
Monsanto	Augusta, Ga.	25,000
Monsanto	Carondelet, Mo.	100,000
Monsanto	Kearny, N. J.	75,000
Monsanto	Long Beach, Calif.	25,000
Monsanto	Trenton, Mich.	75,000
Olin	Joliet, Ill.	140,000
Stauffer	Chicago, Ill.	40,000
Stauffer	Chicago Heights, Ill.	25,000
Stauffer	Morrisville, Pa.	75,000
Stauffer	South Gate, Calif.	50,000
Virginia-Carolina	Fernald, Ohio	50,000
	Total	1,200,000

1/ tons/year

Production: 1969: 1,200,000 tons
1974: 1,600,000 tons

Uses: Detergents.

Processes: The sodium phosphates are made primarily from furnace acid and soda ash which are reacted in a mix tank and dried in a rotary or spray drier and dehydrated in a calciner. This is followed by annealing and cooling in a tempering unit.

Water Problems: Scrubber waters and vessel washouts are major sources of polluted wastewaters.

SIC 2819 (INDUSTRIAL INORGANIC CHEMICALS)

Aluminum Chloride Anhydrous

Producer	Capacity 1/
Allied, Elberta, N. Y.	9,000
Dow, Freeport, Texas	5,000
Hercules Alclor, Ravenna, Ohio	2,400
Pearsall, LaPorte, Texas	4,000
Pearsall, Phillipsburg, N. J.	6,000
Stauffer, Baton Rouge, La.	8,000
Stauffer, Elkton, Md.	8,000
Van de Mark, Lockport, N. Y.	2,500
Total	44,900

1/ tons/year

Production: 1969: 34,000 tons
1974: 44,000 tons

Uses: Ethylbenzene catalyst, dyestuffs, detergent alkylate, ethyl chloride, pharmaceuticals.

Processes: The reaction involves the direct contact of chlorine vapor with molten aluminum. Chlorine is fed below the surface of the aluminum and the product sublimes and is collected by condensing. No change is expected in processing methods.

Waste Problems: The major discharge is a chlorine containing wastewater which could be utilized as a treatment chemical. Recovery of the chlorine by rectification is feasible.

Sulfuric Acid

New Plants Built Since 1966 Include The Following:

Producer	Location	Capacity 1/
Acid, Inc.	Bonnie, Fla.	2,000,000
Arkla Chemical	Helena, Ark.	180,000
American Cyanamid	Linden, N. J.	250,000

Sulfuric Acid (cont.)

Producer	Location	Capacity [1]
American Oil Co.	Texas City, Tex.	150,000
Allied	Geismar, La.	720,000
American Smelting & Refining Co.	Haydon, Ariz.	250,000
American Zinc	Monsanto, Ill.	146,000
	Columbus, Ohio	64,000
Borden Chemical	Plant City, Fla.	385,000
Bunker Hill	Kellogg, Idaho	100,000
DuPont	Burnside, La.	540,000
---	Memphis, Tenn.	75,000
Freeport Sulfur	Uncle Sam, La.	1,725,000
W. R. Grace	Bartow, Fla.	385,000
Kennecott Copper	Hayden, Ariz.	270,000
	Salt Lake City, Utah	505,000
Mo. Lead Smelting	Iron Co., Mo.	75,000
National Zinc	Bartlesville, Okla.	100,000
Olin	Shreveport, La.	125,000
Sinclair	Ft. Madison, Iowa	540,000
Stauffer	Houston, Texas	720,000
Stauffer	Martinez, Calif.	360,000
Tennessee Corp.	Augusta, Ga.	135,000
Texaco	Port Arthur, Tex.	92,000
Texas Gulf Sulfur	Lee Creek, N. C.	1,000,000
	Total	10,892,000

[1] tons/year

Major merchant producers include:

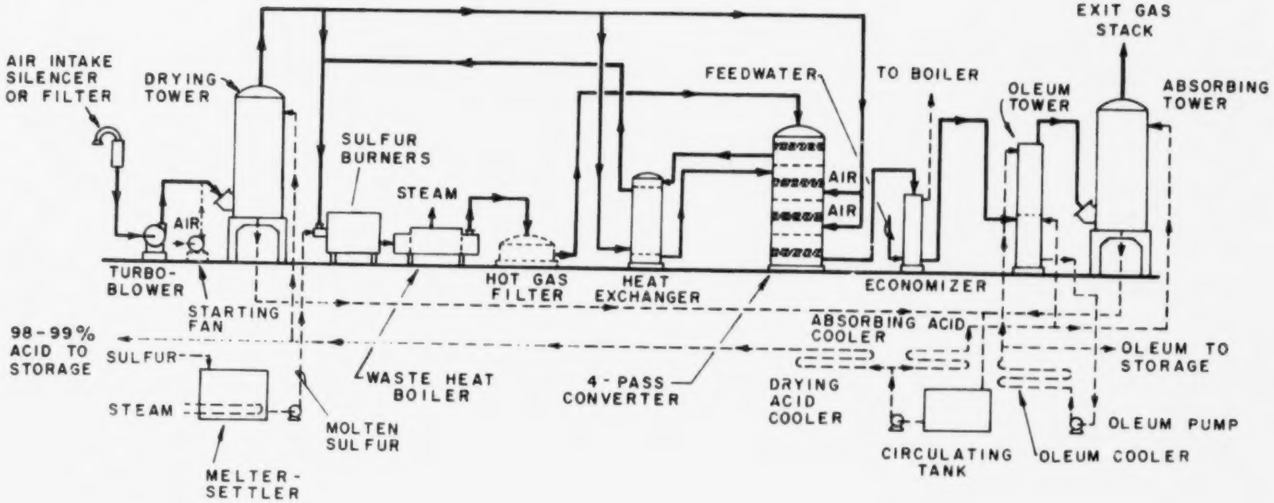
Stauffer Chemical
Allied Chemical
DuPont
American Cyanamid
Tennessee Corporation

Production: 1969: 28,000,000 tons
1974: 34,000,000 tons

Uses: Fertilizer, chemical production, iron and steel pickling, food, petroleum products, metallurgy, TiO_2 production, $(NH_4)_2SO_4$, alum, rayon.

Processes: Two processes have been used for the production of sulfuric acid - the chamber process and the contact process. Since no new chamber processes have been built for perhaps 30 years, the

FIGURE 8


AIR INTAKE SILENCER OR FILTER
DRYING TOWER
AIR
TURBO-BLOWER
STARTING FAN
98-99% ACID TO STORAGE
SULFUR
STEAM
MELTER-SETTLER
MOLTEN SULFUR
SULFUR BURNERS
STEAM
WASTE HEAT BOILER
HOT GAS FILTER
HEAT EXCHANGER
4-PASS CONVERTER
FEEDWATER
AIR
AIR
TO BOILER
ECONOMIZER
ABSORBING ACID COOLER
DRYING ACID COOLER
CIRCULATING TANK
OLEUM TOWER
EXIT GAS STACK
ABSORBING TOWER
OLEUM TO STORAGE
OLEUM PUMP
OLEUM COOLER

TYPICAL FLOWCHART FOR SULFUR-BURNING CONTACT PLANT

This flow chart is selectively reproduced in content and configuration from Figure 19.4 in the book by R. Norris Shreve, *Chemical Process Industries*, Third Edition, New York, Mc Graw-Hill Book Company, 1967, p. 330

following discussion will center on the contact process. In this process, either sulfur or SO_2 may be the starting point. If sulfur is the starting point, it is melted and burnt with air to SO_2. The SO_2 must be filtered and converted catalytically to SO_3. SO_3 is absorbed in strong sulfuric acid. Present process changes are directed towards the improvement in conversion and recovery because of the air pollution problem.

Waste Problems: Primarily from vessel cleanout, and slab washdown as well as discharge of cooling waters.

SIC 2851 (PAINTS AND ALLIED PRODUCTS)

Paints and Allied Products

Producers: There are several hundred paint companies with several thousand paint plants scattered throughout the country. Paint production tends to be a local product because of the high transportation charges. However, Ohio, Illinois, New Jersey and California are major paint-producing centers. Among the leading concerns are the following:

DuPont
National Lead
Sherwin-Williams
Glidden
Moore
Devoe and Reynolds-Celanese

PPG
DeSoto
Mobil
Inmont
Cook

Production:

	1969 (gal)	1974 (gal)
Paint and Varnishes, Total	904,000,000	1,196,000,000
Trade Sales		
Paint and Varnish	438,000,000	587,000,000
Lacquer	11,000,000	15,000,000
Trade Sales, Total	449,000,000	602,000,000
Industrial Product Finishes		
Paint and Varnish	360,000,000	482,000,000
Lacquer	95,000,000	112,000,000
Industrial Product Finishes, Total	455,000,000	594,000,000

Processes: The manufacture of paints involves primarily mixing in tanks although grinding mills, sand mills, high-speed stone mills and high-speed agitators are being increasingly used in these systems. The process is batch type. Finally, color may be added in a tinting and thinning tank before packaging.

Varnish is a solution of a resin in a drying oil or solvent (shellac). This is accomplished by mixing; in some cases, by heating. Finally, the final product is clarified by filtration or centrifugation followed by aging in large tanks to precipitate grit particles.

There has been little change in the manufacture of paints for a century or more and none is expected.

Waste Problems: The major problems arise from tank washings and dumpings. The presence of latex is a specially difficult problem but collection and recycle of the latex is completely possible as is the multiple reuse of wash waters.

SIC 2871 (FERTILIZERS)

Fertilizers

Producers: Fertilizers are generally made by a large number of production facilities located throughout the country. The basic ingredients include: potash, ammonia, ammonium sulfate, ammonium nitrate, ammonium phosphates, plus other phosphate products all of which are prepared in a limited number of large production facilities. Most of these have already been discussed under SIC 2819 but several including potash, super phosphate, triple super and mixed fertilizers will be discussed in this section.

CONCENTRATED SUPER-PHOSPHATE PLANTS
UNITED STATES

Company	Location	Capacity (thou. tons)
American Cyanamid	Brewster, Fla.	180
Armour Agr. Chem. Co.	Ft. Meade, Fla.	113
Borden Chem. Co.	Port Mantee, Fla.	33
Central Phosphates	Plant City, Fla.	155
Cities Service Oil	Tampa, Fla.	165
Coastal Chemical	Pascagoula, Miss.	135 1/
Continental Oil	Pierce, Fla.	180
El Paso Natural Gas	Georgetown, Idaho	55
Farmland Industries	Lakeland, Fla.	36
W. R. Grace & Co.	Joplin, Mo.	32
	Ridgewood, Fla.	350
Int. Minerals & Chem.	Bonnie, Fla.	203
Kerr-McGee	Baltimore, Md.	...
Mobil Chemical	Nichols, Fla.	130
Occidental Agrilcul.	White Springs, Fla.	188
Phillips Chemical	Pasadena, Tex.	45 1/
F. S. Royster Guano	Mulberry, Fla.	170
J. R. Simplot	Pocatello, Idaho	92
Stauffer Chemical	Garfield, Utah	45
	Tacoma, Washington	23
Swift & Company	Agricola, Fla.	77
Tenn. Valley Authority	Muscle Shoals, Ala.	27 2/
Texas Gulf Sulfur	Lee Creek, N. C.	167
	Total	2,601

1/ Idle facilities
2/ High-analysis 54% P_2O_5 material

AMMONIUM AND DIAMMONIUM PHOSPHATE PLANTS
UNITED STATES

Company	Location	Capacity (thousand tons/year)
AFC, Inc.	Edison, Calif.	28
Allied Chemical	Geismar, La.	-
American Cyanamid	Brewster, Fla.	91
Arizona Agrochemical	Chandler, Ariz.	18
Arkla Chemical	Helena, Ark.	-
Armour Agri. Chem.	Bartow, Fla.	15
	Cherokee, Ala.	75
Borden Chemical	Port Manatee, Fla.	85
	Streator, Ill.	25
	Texas City, Tex.	45
Bunker Hill	Kellogg, Idaho	15
Central Phosphates	Plant City, Fla.	NK 1/
Chevron Chemical	Ft. Madison, Iowa	NK 1/
	Kennewick, Wash.	NK 1/
	Richmond, Calif.	NK 1/
Cities Service Oil	Tampa, Fla.	179
Coastal Chemical	Pascagoula, Miss.	120
Colorado Fuel & Iron	Pueblo, Colo.	7 2/
Continental Oil	Pierce, Fla.	46
Des Plaines Chemical	Morris, Ill.	34
Dominguez Fertilizer	Long Beach, Calif.	15
El Paso Nat. Gas	Soda Springs, Idaho	30
Farmland Industries	Lakeland, Fla.	147
	Joplin, Mo.	67
Ford Motor	Dearborn, Mich.	10 2/
W. R. Grace	Henry, Ill.	100
	Joplin, Mo.	20
	Ridgewood, Fla.	174
Hooker Chemical	Marseilles, Ill.	69
	Taft, La.	175
Int. Min. & Chem.	Bonnie, Fla.	230
Kaiser Steel	Fontana, Calif.	15
Mobil Chemical	Nichols, Fla.	77
Monsanto	Luling, La.	120
Nat. Dist. & Chem.	Danville, Ill.	15
N. J. Zinc	Depue, Ill.	124
Nipak, Inc.	Kerens, Tex.	46
	Tulsa, Okla.	20
NW Coop. Mills	Pine Bend, Minn.	69
Occidental Agri.	White Springs, Fla.	115
	Lathrop, Calif.	10
	Plainview, Tex.	9

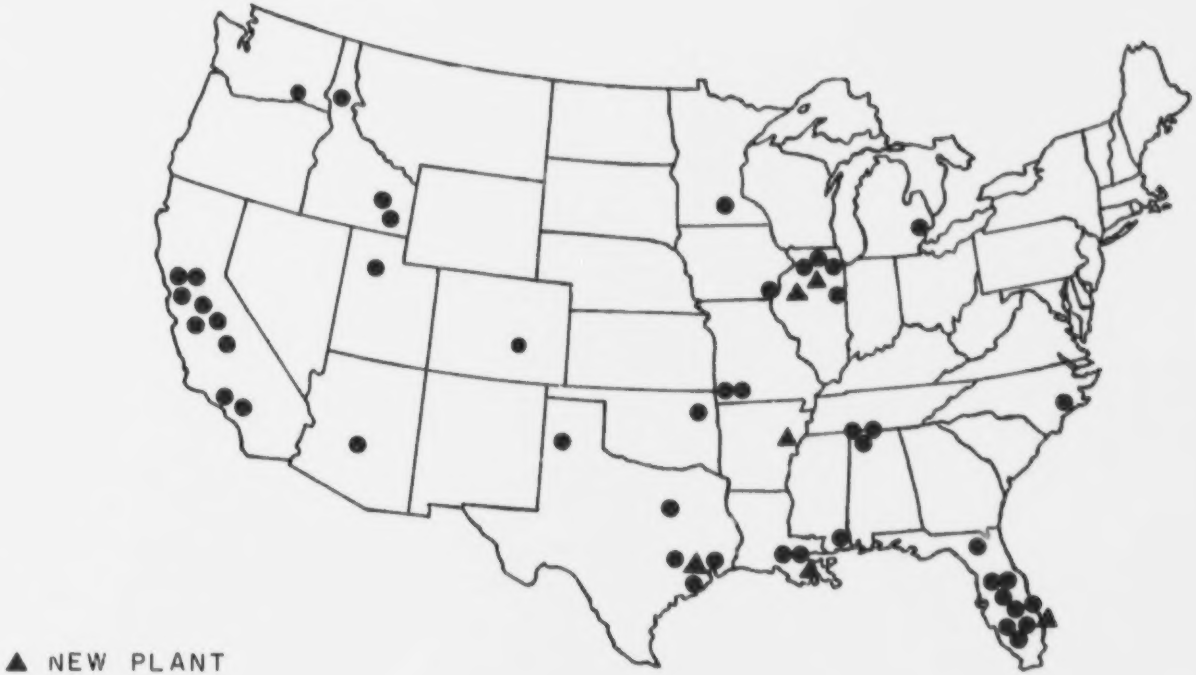
AMMONIUM AND DIAMMONIUM PHOSPHATE PLANTS (cont.)

Company	Location	Capacity (thousand tons/year)
Olin Mathieson Chem.	Pasadena, Tex.	200
Phosphate Chemicals	Houston, Tex.	69
F. S. Royster Guano	Mulberry, Fla.	41
Shell Chemical	Pittsburg, Calif.	12 2/
J. R. Simplot	Pocatello, Idaho	91
Stauffer Chemical	Garfield, Utah	80
Swift	Agricola, Fla.	69
Tennessee Farmers	Sheffield, Ala.	NK 1/
Tennessee Valley Auth.	Muscle Shoals, Ala.	15 2/
Texas Gulf Sulfur	Lee Creek, N. C.	105
Union Oil of Calif.	Brea, Calif.	12
Valley Nitrogen Prod.	Helm, Calif.	35
Western States Chem.	Nichols, Calif.	NK 1/
	Total	3,169

1/ Nitric phosphate process
2/ Diammonium phosphate 21-53-0 analysis

AMMONIUM PHOSPHATE PLANT LOCATIONS

FIGURE 9



PHOSPHATE ROCK MINES
UNITED STATES

Company	Location	Capacity (thousand short tons)
	Florida	
American Cyanamid	Brewster	3,650
Armour Agr. Chem.	Amour Lake Hancock	1,500
Armour Agr. Chem. & Freeport Sulfur	Ft. Meade	2,000
Borden Chemical	Teneroc	1,500
Cities Service	Ft. Meade	2,000
Continental Oil	Pierce	6,500
W. R. Grace	Bonny Lake	1,550
Int. Min. & Chem.	Bonnie	6,000
	Kingsford	2,000
Kerr-McGee, Inc.	Brewster	1,500
Mobil Chemical	Ft. Meade	5,700
Occidental Agril.	White Springs	3,000
Swift & Co.	Watson Silver City	2,325
	North Carolina	
Texas Gulf Sulfur	Lee Creek	3,000
	Tennessee	
Armour Agril. Chem.	Columbia	90
Hooker Chemical	Columbia	750
Mobil Chemical	Mt. Pleasant	200
Monsanto	Columbia	1,000
Presnell Phosphate	Columbia	700
Stauffer Chemical	Mt. Pleasant	600
Tennessee Valley Auth.	Knob Creek Franklin	200
	Western States	
Cominco Ltd.	Garrison, Mont. Phillipsburg, Mont.	1,050
El Paso Nat. Gas	Soda Springs, Idaho	400
Monsanto	Ballard, Idaho	500
Mountain Fuel Supply	Soda Springs, Idaho	NK
New Idria Mining & Chemical	Bakersfield, Calif.	NK
George Relyea	Garrison, Mont.	100
J. R. Simplot	Fort Hall, Idaho Soda Springs, Idaho	1,600

PHOSPHATE ROCK MINES (cont.)

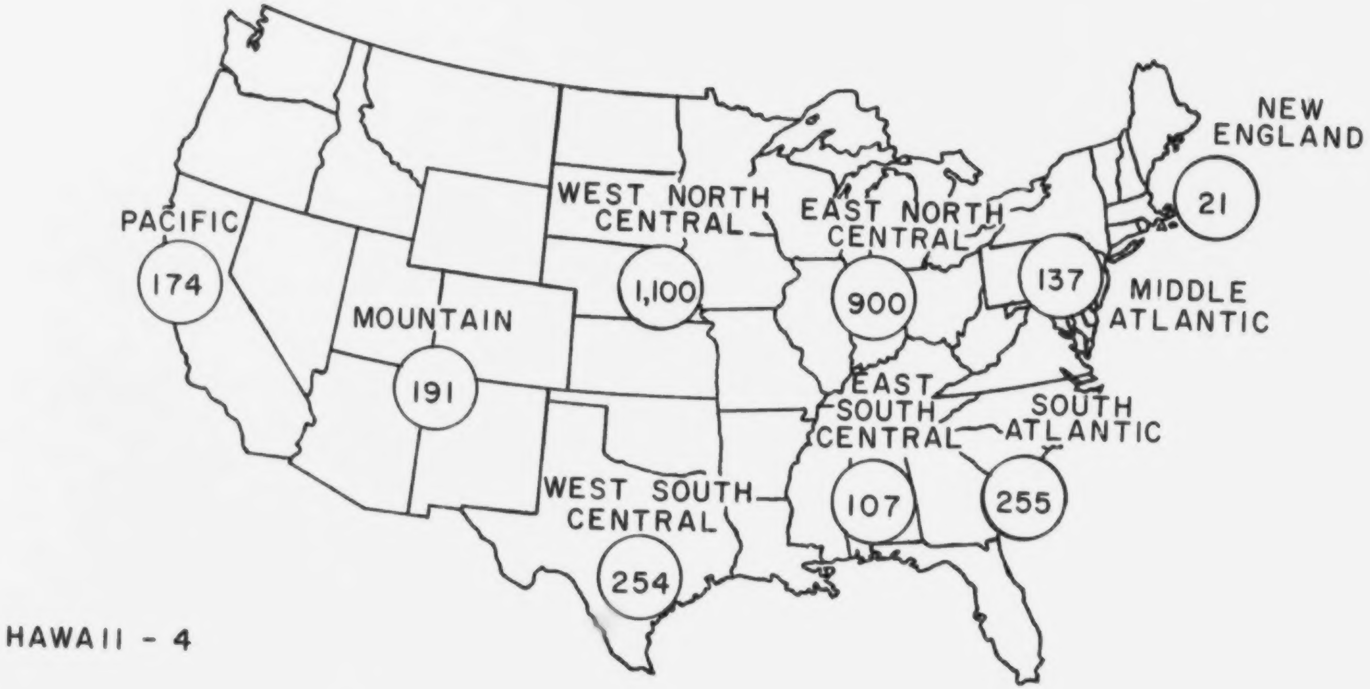
Company	Location	Capacity (thousand short tons)
Stauffer Chemical	Hot Springs, Idaho	200
	Montpelier, Idaho	
	Cherokee, Utah	400
	Vernal, Utah	200
	Leefe, Wyo.	350
	Melrose, Mont.	600
	Total United States	51,165

ESTIMATED NUMBER OF BULK BLEND PLANTS IN THE UNITED STATES

State	No. of Plants 1966
Maine	3
New Hampshire	1
Vermont	3
Massachusetts	5
Rhode Island	5
Connecticut	4
NEW ENGLAND	21
New York	39
New Jersey	20
Pennsylvania	44
Delaware	7
Maryland	26
West Virginia	1
MIDDLE ATLANTIC	137
Virginia	15
North Carolina	41
South Carolina	28
Georgia	76
Florida	95
SOUTH ATLANTIC	255
Ohio	100
Indiana	235
Illinois	428
Michigan	55
Wisconsin	82
EAST NORTH CENTRAL	900
Minnesota	192
Iowa	426
Missouri	224
North Dakota	17
South Dakota	33
Nebraska	116
Kansas	102
WEST NORTH CENTRAL	1,110
Kentucky	35
Tennessee	17
Alabama	37
Mississippi	18
EAST SOUTH CENTRAL	107
Arkansas	50
Louisiana	23
Oklahoma	56
Texas	125
WEST SOUTH CENTRAL	254
Montana	11
Idaho	43
Wyoming	29
Colorado	53
New Mexico	15
Arizona	13
Utah	27
Nevada	--
MOUNTAIN	191
Washington	49
Oregon	42
California	83
PACIFIC	174
Total Continental U.S.	3,149
Hawaii	4
TOTAL U.S.	3,153

ESTIMATED NUMBER OF BULK BLEND FERTILIZER PLANTS

FIGURE 10


PACIFIC
174
MOUNTAIN
191
WEST NORTH CENTRAL
1,100
WEST SOUTH CENTRAL
254
EAST NORTH CENTRAL
900
EAST SOUTH CENTRAL
107
SOUTH ATLANTIC
255
MIDDLE ATLANTIC
137
NEW ENGLAND
21
HAWAII - 4

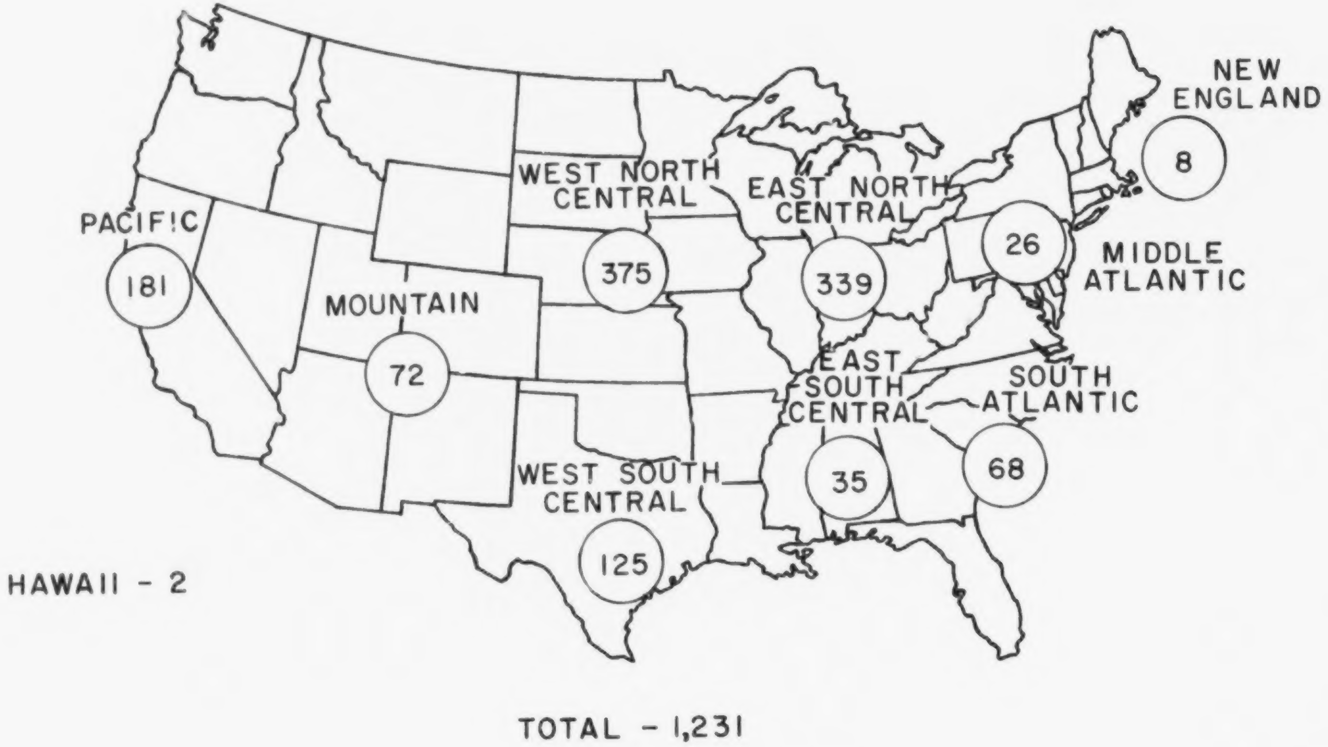
TOTAL - 3, 153

ESTIMATED NUMBER OF LIQUID MIX PLANTS IN THE UNITED STATES

State	No. of Plants 1966
Maine	1
New Hampshire	-
Vermont	2
Massachusetts	4
Rhode Island	-
Connecticut	1
NEW ENGLAND	8
New York	6
New Jersey	5
Pennsylvania	8
Delaware	1
Maryland	6
West Virginia	-
MIDDLE ATLANTIC	26
Virginia	11
North Carolina	11
South Carolina	7
Georgia	12
Florida	27
SOUTH ATLANTIC	68
Ohio	29
Indiana	129
Illinois	154
Michigan	12
Wisconsin	15
EAST NORTH CENTRAL	339
Minnesota	41
Iowa	85
Missouri	63
North Dakota	5
South Dakota	7
Nebraska	49
Kansas	125
WEST NORTH CENTRAL	375
Kentucky	7
Tennessee	3
Alabama	6
Mississippi	19
EAST SOUTH CENTRAL	35
Arkansas	19
Louisiana	15
Oklahoma	24
Texas	67
WEST SOUTH CENTRAL	125
Montana	4
Idaho	24
Wyoming	5
Colorado	16
New Mexico	1
Arizona	19
Utah	1
Nevada	2
MOUNTAIN	72
Washington	55
Oregon	17
California	109
PACIFIC	181
Total Continental U.S.	1,229
Hawaii	2
TOTAL U.S.	1,231

ESTIMATED NUMBER OF LIQUID MIXED FERTILIZER PLANTS

FIGURE 11


NEW ENGLAND
8
MIDDLE ATLANTIC
26
EAST NORTH CENTRAL
339
WEST NORTH CENTRAL
375
SOUTH ATLANTIC
68
EAST SOUTH CENTRAL
35
WEST SOUTH CENTRAL
125
MOUNTAIN
72
PACIFIC
181
HAWAII - 2
TOTAL - 1,231

Production: (100% APA)

	Normal Super	Triple Super	Ammonium Phosphates	Other Phosphatic Fertilizer
1969	913,000	1,390,000	1,651,000	
1974	900,000	1,800,000	2,200,000	

Processes: Superphosphate is solubilized phosphate rock in which the rock is acidulized with sufficient acid to convert the rock to monocalcium phosphate and gypsum. No separation is made. The waste products and processes except for the gypsum are similar to those generated in the production of phosphoric acid.

Concentrated superphosphate is produced by the reaction of phosphoric acid with phosphate rock producing Ca $(H_2PO_4)_2$. No gypsum is produced. The reaction takes place in a rotating granulator. The major waste products are the scrubber waters from the granulator and subsequent cooler exhaust gas scrubbers which contain some phosphoric and considerable amounts of silico fluorides for which a considerable market exists. The condensate from the acid preheater can be used for scrubber water to close loop the system. Normal super production is being superseded by triple production.

Phosphate rock handling results in a heavily turbid water flow. Solids settling is usually practiced.

Ammonium phosphate is produced by the direct contact of phosphoric acid and ammonia. Vessel washout is the major pollutional source.

Liquid mix and dry mix plants involve the blending of fertilizer base materials such as superphosphate, urea, ammonium nitrate, ammonium phosphate and potash thereby producing the final product. Vessel washout is the major pollutional problem.

Potash is produced from sedimentary deposits of syluinite (a mixture of K Cl and Na Cl) and langbeinite $(K_2SO_4 \cdot 2MgSO_4)$, primarily. Langbeinite is processed to produce potassium sulfate. The Trona, California, salts are another important salt. Solar evaporation at Great Salt Lake is also practiced. The biggest single source of new potash is the deep deposit in Saskatchewan, Canada which will be developed by conventional and solution mining.

Some of the potash is produced by fractional crystallization but the syluinite deposits are handled by either soap flotation or fractional solution. In both processes, slimes and reject salt solutions are present to create pollution problems. The reject salt solutions may contain small amounts of flotation agents such as starch and amines. It is possible through the careful use and selection of these agents to minimize losses. Reuse and recovery of the slimes and salt solutions may be practiced. Of course, since great stretches of land are available, disposal is not generally a problem. In Europe, the great potash mines of the Alsace are one of the main polluters of the Rhine. Recovery of the salt is totally feasible. The present trend is towards partial solution of KCl as practiced in Canada since this area will be the major source in the next decade.

Complex fertilizer is prepared by reaction of ammonia, phosphoric acid, nitric acid and phosphate rock in acidulation tanks. The final slurry is mixed with potassium chloride (potash). The product may be spherodized, granulated or coated. A dust collector is used to recover fines.

Generally, the entire system is kept dry for process reasons but vessel and slab washdowns produce wastewater problems. Fluorine in fume scrubbing water may be a problem.

TVA has been successful in developing direct ammination and acidulation processes aimed at producing higher concentration fertilizers. Most of these processes are carried out dry, but this is not the universal practice and those processes carried out in a wet state create steady waste streams. The trend towards high analysis fertilizer is expected to continue in the future.

POTASH PLANTS
UNITED STATES AND CANADA

Company	Location	1969 Capacity (thou. tons)
	United States	
American Metal Climax	Carlsbad, N. M.	600
Am. Potash & Chem.	Trona, Calif.	235
	Carlsbad, N. M.	450
	Carlsbad, N. M.	450
	Wendover, Utah	66
	Carlsbad, N. M.	300
	Ogden, Utah	270
	Carlsbad, N. M.	350
	Carlsbad, N. M.	620
	Moab, Utah	350
U.S. Borax & Chem.	Carlsbad, N. M.	550
Agri. Minerals	Davenport, Calif.	
Dow Chemical	Midland, Mich.	10
N. Am. Cement	Security, Md.	
	Total	4,251
	Canada	
	Lanigan, Sask,	600
	Delisle, Sask.	600
	Saskatoon, Sask.	600
Int. Min. & Chem.	Esterhazy, Sask.	2,460
Calium Chemicals	Belle Plaine, Sask.	360
	Viscount, Sask.	720
Potash Corp. of Am.	Lake Patience, Sask.	430
U.S. Borax & Chem.	Saskatoon, Sask,	900
	Total	6,670
	Total North America	10,921

SIC 2879 (INORGANIC PESTICIDES)

Inorganic Pesticides

Producers: Data not available

Production: (tons/year)	1969	1974
Arsenic compounds	6,000	5,000
Sulfur	210,000	150,000

Processes and Waste Problems: In general, inorganic compounds have been replaced by organic compounds. The major inorganic pesticides are the following:

lead arsenate
sulfur
carbon bisulfide
hydrogen cyanide
fluorine
lime-sulfurs
Bordeaux mixture
mercury chlorides
sodium chlorate
sodium arsenite
ammonium sulfamate

This review does not consider the organophosphorous compounds which are gaining major importance in the industry. Neither will this review detail many of the above listed chemicals because their use in this particular application is minor compared to other uses for them.

Lead arsenate is prepared from lead oxide which is dissolved in acetic and nitric acid and arsenic acid is added. Lead arsenate is removed by filtration. The mixture of nitric and acetic acid is reused three times. Thus, 0.15 pounds of nitric acid per pound of product and a similar amount of acetic acid is discarded or must be treated and recycled. It is obvious that recycle would result in greatly reduced waste problems.

Sulfur is made by milling sulfur to 325 mesh, emulsifying molten sulfur, heating mixtures of sulfur with bentonite and using flotation sulfur obtained from the recovery of the element from hydrogen sulfide from gases. Washout streams containing fine sulfur particles can be recovered.

Lime-sulfur is prepared by boiling a mixture of lime, sulfur and water to a dry mixture.

Bordeaux mixture is prepared by mixing copper sulfate, lime and water. Both lime sulfur and Bordeaux mixture are generally prepared in the field and wastewater problems are not significant.

Mercury chlorides are prepared in the following fashion. Mercuric chloride is prepared by the direct reaction of mercury and chlorine and mercurous chloride is made by reducing mercuric chloride with mercury. Wastewater problems result from vessel washout.

Considering the fading nature of the industry, no process changes are expected.

SIC 2892 (EXPLOSIVES)

Explosives

Producer: Data not available

Production: 1969: ($) 264,000,000
1974: ($) 322,000,000
(weight data not available)

Processes and Waste Problems: Nitrocellulose is prepared first by boiling cotton linters in dilute caustic and bleaching with chlorate. The cotton is then dried and nitrification with nitric acid and sulfuric acid takes place in a nitrator. The charge is dropped into a centrifuge for drying.

Two waste problems exist. The kiering caustic solution must be dumped from time to time and this is a serious waste load. Regeneration of the caustic solution by dialysis or other membrane processes is possible but not practical.

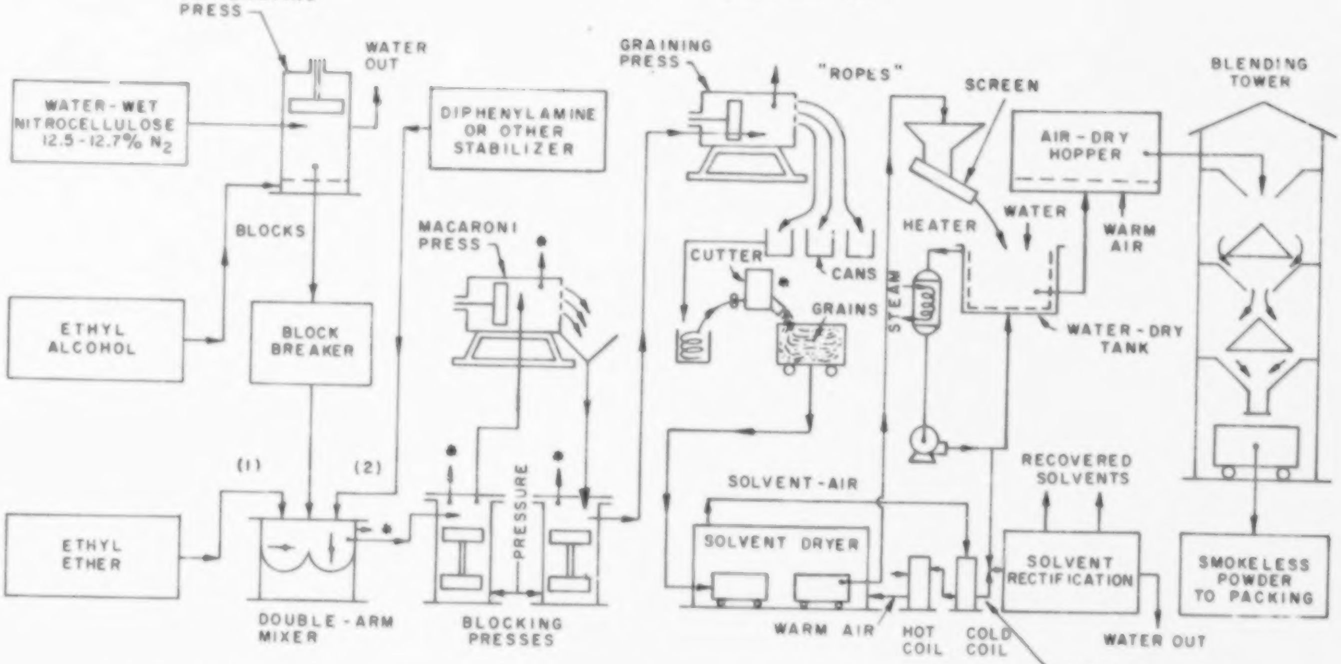
The waste acid amounts to 0.5 pounds of sulfuric and 0.35 pounds of nitric. Some of this acid is sent for concentration, some is sold and the remainder is discharged. Reuse of this acid should be possible if careful measures are taken.

Naturally, washouts of vessels and slabs can also produce major waste treatment problems.

Smokeless powder is washed and beaten to remove free acid and destroy any unstable sulfate esters that may have been formed. The final product is colloidized by mixing with alcohol, ether, diphenylamine and other modifying agents. Again, the washing of the nitro cellulose produces a waste containing sulfuric and nitric acid which can be reclaimed in a fortifying plant.

TNT is produced by the three stage nitrification of toluene followed by soda ash and sodium sulfate washes. The wash water contains considerable amounts of alkalies and sodium dinitrosulfanates.

FIGURE 12


DEHYDRATING PRESS
WATER OUT
WATER-WET NITROCELLULOSE 12.5-12.7% N_2
BLOCKS
ETHYL ALCOHOL
BLOCK BREAKER
ETHYL ETHER
(1)
(2)
DOUBLE-ARM MIXER
DIPHENYLAMINE OR OTHER STABILIZER
MACARONI PRESS
PRESSURE
BLOCKING PRESSES
GRAINING PRESS
"ROPES"
CUTTER
CANS
GRAINS
SOLVENT-AIR
SOLVENT DRYER
WARM AIR
HOT COIL
COLD COIL
MIXED SOLVENTS AND WATER
SCREEN
HEATER
STEAM
WATER
WATER-DRY TANK
AIR-DRY HOPPER
WARM AIR
RECOVERED SOLVENTS
SOLVENT RECTIFICATION
WATER OUT
BLENDING TOWER
SMOKELESS POWDER TO PACKING

* NOTE: ASTERISKS DENOTE EQUIPMENT CONNECTED TO SOLVENT RECOVERY SYSTEM

FLOWCHART FOR SMOKELESS POWDER

This flow chart is selectively reproduced in content and configuration from Figure 22.4 in the book by R. Norris Shreve, *Chemical Process Industries*, Third Edition, New York, Mc Graw-Hill Book Company, 1967, p. 390

Ammonium nitrate - Fuel oil (AN) are produced by mixing and shaping of the two ingredients. A major waste source is from the washing of the equipment, thereby producing a waste stream containing oil and a high nitrogen content.

Nitroglycerin and dynamite. Nitration of the glycerin takes place in the presence of sulfuric acid. The nitroglycerin is separated from the spent acids and washed several times. The spent acid is recycled and fortified. About 80 pounds of sulfuric and 160 pounds of nitric are wasted from the system per ton of nitroglycerine. Dynamite is made by adsorbing nitroglycerine on agents such as wood flour, ammonium nitrate or sodium nitrate. Nonfreezing dynamite can be made by the addition of ethylene glycol dinitrate to lower the freezing point of nitroglycerine. A typical waste from a dynamite-nitroglycerine facility has the following composition: pH-7, COD-350 ppm, TDS-10,800 ppm, SS-40, sodium-150, ammonia-nitrogen-1270 ppm, nitrate nitrogen-550 ppm, sulfates-1000 ppm.

APPENDIX D

QUALITATIVE PERSONNEL REQUIREMENTS FOR TREATMENT PROCESSES - TASK ENUMERATIONS

Chemical Addition

Equalization

Oil Removal

Sedimentation

Filtration

Reverse Osmosis

Electrodialysis

Ion Exchange

Multiple Effect Evaporators

Deep Well Injection

Lagooning/Cooling Ponds/Solar Evaporation Ponds

Centrifugation

Cooling Towers

CHEMICAL ADDITION	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Operations			
Monitors and verifies proper operation and condition of the following units of equipment:			
Dry volumetric feeders	OP	2	1/Shift
Liquid displacement feeders	"	2	"
pH status and control instruments	"	2	"
Conductivity status and control instrumentation	"	2	"
Electric motors, relays, and circuit breakers/ switches	"	2	"
Centrifugal, reciprocating, and diaphragm pumps	"	2	"
Flow measuring devices	"	2	"
Iron, steel, glass, copper, plastic pipe and fittings	"	1	"
Manual and automatic control valves	"	2	"
Steel, lined steel, and wood tanks, drums, and vessels	"	1	"
Mixing and blending equipment (electrically driven)	"	2	"
Belt, chain, and gear drive mechanisms	"	2	"
Reads and interprets status and control instrumentation:			
pH recorders and meters	"	2	"
Conductivity recorders and meters	"	2	"
Flow recorders and meters	"	2	"
Level indicators	"	2	"
Pressure recorders and meters	"	2	"
Pilot lamps and voltage/current recorders and meters	"	2	"

CHEMICAL ADDITION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Volume recorders and meters	OP	2	1/Shift
Weight measuring devices	"	2	"
Maintains supplies for chemical feeding equipment (refills, tanks and hoppers):			
Measures, weighs, and mixes chemicals	"	2	As Req
Activates, controls units of equipment:			
Adjusts and calibrates feed rate on dry volumetric and liquid displacement feeders	"	3	"
Switches to standby or parallel pumps	"	2	"
Adjusts electrical motor speeds	"	2	"
Overrides automatic controls to correct in specific situations	"	3	"
Adjusts manual valves to achieve specified flow, pressure, or volume	"	2	"
Adjusts speed of mixing and blending equipment	"	2	"
Collects composite or grab samples for laboratory analysis	"	2	1/Shift
Preventive Maintenance Activities			
Services dry chemical feeders:			
Removes chemical dust accumulations from hoppers and feed mechanism	"	2	wkly
Checks for loose bolts and defective parts	"	2	dly
Cleans solution tanks of accumulated sediment	"	2	wkly
Lubricates drive mechanism and moving parts	"	2	dly

CHEMICAL ADDITION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks for rust/corrosion	OP	1	wkly
Checks rate of feed against known standard	"	3	wkly
Paints exposed parts	"	1	yrly
Services liquid displacement feeders:			
Cleans sediment from trap and chemical storage tanks	"	2	wkly
Checks for loose or defective parts	"	2	dly
Lubricates moving parts and drive mechanisms	"	2	dly
Checks pilot tubes and needle valves for proper operation	"	2	dly
Checks rate of feed against known standard	"	3	wkly
Paints exposed parts	"	1	yrly
Services status and control instrumentation:			
Cleans and lubricates chart drive mechanisms	"	2	2/yr
Cleans electrical sensors	"	2	mthly
Checks electrical contacts, connections, and wiring	"	2	wkly
Checks pneumatic sensors for leaks	"	2	wkly
Checks zero or null setting on galvanometers and on pen recorders	"	2	wkly
Checks mechanical linkage for corrosion, rust, and freedom of movement	"	2	wkly
Cleans indicator covers and glass viewing windows	"	2	mthly
Cleans recorder pens and checks for ink flow	"	2	dly
Checks indicated valves against known standards (checks calibration)	"	3	mthly

CHEMICAL ADDITION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Services electric motors and auxiliary equipment:			
Inspects motors for signs of overheating	OP	2	dly
Checks for excessive vibration or hum	"	2	dly
Checks wiring insulation	"	2	wkly
Checks for dirt or moisture	"	2	dly
Checks drive coupling and motor mounts for play/loose fittings	"	2	dly
Checks for sticking brushes or excessive arcing	"	2	dly
Checks pilot lights and alarms	"	2	1/Shift
Checks points and contacts for pitting	"	2	mthly
Cleans and tightens electrical connections	"	2	mthly
Checks and lubricates bearings	"	1	wkly
Checks switches and circuit breakers for proper functioning	"	2	dly
Services centrifugal, reciprocating, and diaphragm pumps:			
Checks solenoid oiler flow; adjusts as necessary	"	2	wkly
Checks oil level in ball bearing housing; fills as necessary	"	1	dly
Checks grease cup; maintains proper pressure	"	2	dly
Checks enclosed shaft bearings; refills oil cup as necessary	"	2	dly
Checks ball-thrust bearings; adds fresh grease as necessary	"	2	mthly
Checks guide bearings; adds grease as necessary	"	2	wkly
Drains and adds fresh lubricant to shaft bearings	"	2	mthly

CHEMICAL ADDITION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Flushes bearing housing and adds fresh grease	OP	2	4/yr
Checks bearing temperatures; adjusts as necessary	"	2	wkly
Checks stuffing boxes for leaks; tightens or repacks as necessary	"	2	dly
Checks water-seal systems for leaks; adjusts pressure as necessary	"	2	dly
Clean and paint pump casting	"	1	dly
Check, clean, lubricate, and adjust float switch system	"	2	wkly
Inspect check valves for leaks	"	2	dly
Clean sediment and accumulated solids from sumps	"	1	mthly
Check and clean strainers	"	1	dly
Services flow measuring devices:			
Cleans and flushes annular chambers	"	2	mthly
Cleans and flushes piezometer pressure taps	"	2	mthly
Cleans and dresses orifice plates	"	2	2/yr
Cleans and paints exterior	"	1	yrly
Inspects interior for corrosion	"	2	mthly
Purges connecting lines and fittings	"	2	wkly
Services pipes and pipe fittings:			
Checks for leaks in pipes and pipe fittings	"	1	wkly
Inspects for rust and corrosion	"	1	wkly
Cleans and paints pipes and fittings	"	1	yrly
Flushes dead-ends	"	2	mthly
Checks and cleans sediment traps	"	1	wkly

CHEMICAL ADDITION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks and cleans wells and sumps	OP	1	wkly
Mechanically cleans pipes with augers and snakes	"	2	yrly
Services manual and automatic control valves:			
Checks valves for leaks	"	2	dly
Inspects for rust and corrosion	"	2	wkly
Checks actuating bellows for leaks	"	2	dly
Checks linkages for free movement	"	2	dly
Checks for complete opening and closing	"	2	dly
Checks calibration	"	3	mthly
Lubricates control linkage	"	2	wkly
Adjusts packing	"	2	wkly
Cleans and paints exterior	"	1	yrly
Cleans solenoid actuating mechanisms	"	2	dly
Services storage tanks, drums, and vessels:			
Checks for leaks	"	1	dly
Inspects for rust and corrosion	"	1	wkly
Cleans and paints interior and exterior	"	1	yrly
Removes accumulated deposits of sludge and sediment	"	1	wkly
Services mixing and blending equipment:			
Cleans deposits from paddles, arms, and propellers	"	1	wkly
Inspects for rust and corrosion	"	1	wkly
Inspects mechanical drive functioning	"	2	wkly
Lubricates mechanical drive system	"	2	wkly
Paints and protects exposed surfaces	"	1	yrly

CHEMICAL ADDITION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks for homogeneity of mixed substances	OP	2	dly
Checks speed of mixing or blending	"	2	dly
Services mechanical drive systems:			
Checks tension of flat and V-belt drives	"	2	dly
Checks and adjusts belt alignment	"	2	dly
Checks belts for wear	"	2	wkly
Checks and adjusts chain drive slack	"	2	wkly
Lubricates chain drive systems	"	2	wkly
Checks lubricant levels in right-angle gear drives	"	2	wkly
Checks lubricant levels in reduction gear boxes	"	2	wkly
Drains and changes oil in sump systems	"	2	mthly
Cleans and inspects variable speed belt drive systems	"	2	wkly
Lubricates thrust and frame bearings for drive shafts	"	2	wkly
Checks oil seals for leaks	"	2	dly
Lubricates pressure grease fittings	"	2	wkly
Corrective Maintenance Activities			
Repairs and overhauls dry chemical feeders:			
Troubleshoots and diagnoses malfunctions	Mech Main	3	As Req
Installs, removes, and replaces chemical feeder units	"	3	"
Inspects and measures parts for wear and defects	"	3	"

CHEMICAL ADDITION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks and adjusts stroke rods	Mech Main	3	As Req
Cleans pockets of star feeder and scraper	"	3	"
Checks and cleans feeding gates	"	3	"
Checks feeder scale sensitivity and null balance	"	3	"
Replaces worn or defective parts and bearings	"	3	"
Fits parts, seals, and gaskets	"	3	"
Reassembles feeding unit	"	3	"
Tests and calibrates feed rate against known standard	"	3	"
Cleans and paints all exposed surfaces	"	1	"
Repairs and overhauls liquid and solution chemical feeders:			
Troubleshoots and diagnoses malfunctions	"	3	"
Installs, removes, and replaces chemical feeder units	"	3	"
Disassembles feeder units and reassembles	"	3	"
Inspects and measures parts for wear and defects	"	3	"
Repairs linings and diaphragms	"	3	"
Measures and adjusts float valve settings	"	3	"
Fits parts, seals, and gaskets	"	3	"
Replaces worn or defective parts, seals, and gaskets	"	3	"
Tests and calibrates feed rate against known standard	"	3	"
Cleans and paints all exposed surfaces	"	1	"

CHEMICAL ADDITION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repairs and overhauls status and control instrumentation:			
Troubleshoots and diagnoses malfunctions in status and control instrumentation	Ins Repmn	3	As Req
Installs, removes, replaces status and control instrumentation	"	3	"
Disassembles and reassembles status and control instrumentation	"	3	"
Tests diaphragms, bourdon tubes, and bellows for leaks or defects	"	3	"
Tests bimetallic strips and thermocouples for defects	"	3	"
Tests electrical circuitry for shorts, open circuits, and resistance	"	3	"
Cleans and adds mercury to manometers	"	3	"
Cleans and sets contact points	"	3	"
Cleans and checks knife edges	"	3	"
Cleans and lubricates jeweled bearings	"	3	"
Blows down pressure lines to remove restrictions or stoppages	"	3	"
Cleans and checks orifices and nozzles	"	3	"
Adjusts backlash in mechanical linkages	"	3	"
Calibrates indicators and recorder pen against known standard	"	3	"
Replaces worn or defective parts, seals, and bearings	"	3	"
Repairs and overhauls electric motors and auxiliary equipment:			
Diagnoses and troubleshoots electrical malfunctions	Elec	3	"

CHEMICAL ADDITION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f.
Installs, removes, replaces electric motors, wiring, and control devices	Elec	3	As Req
Inspects and tests rotor and stator windings for shorts or open circuits	"	3	"
Inspects commutator for wear, shorts, and signs of excessive heat	"	3	"
Checks brushes for wear and proper spring tension	"	3	"
Adjusts brushes to seat properly and prevent sticking	"	3	"
Cleans, adjusts, and lubricates bearings	"	3	"
Checks thermal switches, circuit breakers, and fuses	"	3	"
Cleans and polishes collector rings	"	3	"
Checks and tightens pigtails and mechanical wire connections	"	3	"
Replaces or repairs defective parts in motors and control devices	"	3	"
Adjusts rotor and shaft alignment	"	3	"
Reconditions or replaces contacts on relays and switches	"	3	"
Replaces defective wiring and conduit	"	3	"
Inspects exposed equipment for defective gaskets and seals	"	3	"
Measures voltage, current, and power consumption	"	3	"
Checks motor speeds	"	3	"

CHEMICAL ADDITION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repairs and overhauls centrifugal, reciprocating, and diaphragm pumps:			
Troubleshoots and diagnoses malfunctions in pumps	Pump Serv	3	As Req
Installs, removes, and replaces pumps	"	3	"
Disassembles and assembles pumps	"	3	"
Inspects and measures bearings and bearing races for defects	"	3	"
Repacks ball-thurst bearings, roller bearings, and guide bearings	"	3	"
Cleans and inspects pump interior	"	3	"
Checks stuffing box for free movement of gland and excessive leakage	"	3	"
Repacks gland assembly and adjusts	"	3	"
Grinds and laps valves and valve seats	"	3	"
Inspects impellers for deposits, scaling, and cavitation pits	"	3	"
Dynamically balances impellers	"	3	"
Checks and aligns drive system	"	3	"
Fits replacement parts	"	3	"
Repairs bent float rods, binding mechanical fittings	"	3	"
Lubricates mechanical fittings	"	3	"
Cleans and paints exterior housing	"	1	"
Repairs and replaces pipes and pipe fittings:			
Troubleshoots and diagnoses nature and location of stoppages	Pipe Ftr	3	"
Removes and replaces sections of pipe, pipe fittings, and coolings	"	3	"

CHEMICAL ADDITION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Cuts and threads pipe	Pipe Ftr	3	As Req
Cleans pipe using mechanical and hydraulically propelled tools	"	3	"
Replaces gaskets and seals on flange type joints	"	3	"
Bends pipe and tubing	"	3	"
Tests pipe systems for pressure capability and leaks	"	3	"
May be required to repair and replace special purpose pipe and fittings of the following types:			
Glass	"	3	"
Glass or plastic lined steel	"	3	"
Plastic and PVC	"	3	"
Aluminum	"	3	"
Wood	"	3	"
Vitrified tile	"	3	"
Repairs and overhauls manual and automatic control valves:			
Troubleshoots and diagnoses malfunction in manual and controlled valves	Ins Repmn	3	As Req
Installs, removes, and replaces valves	"	3	"
Assembles and disassembles valves and control mechanisms	"	3	"
Inspects and measures valve clearances	"	3	"
Grinds, polishes, laps-in valves and valve seats	"	3	"
Cleans and inspects valve actuating mechanisms	"	3	"
Adjusts backlash in valve actuating mechanisms	"	3	"

CHEMICAL ADDITION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Lubricates valve actuating mechanisms	Ins Repmn	3	As Req
Tests bellows and diaphragm actuators for leaks	"	3	"
Calibrates valve position and control actuator	"	3	"
Adjusts and replaces packing and seals	"	3	"
Tests valves for complete opening and shut-off	"	3	"
Tests functioning of control actuators (pneumatic, hydraulic, electrical, mechanical)	"	3	"
Replaces worn or defective valve and actuator parts	"	3	"
Repairs and overhauls storage tanks, drums and vessels:			
Repairs leaks and defective portions of steel storage facilities	Mech Main	3	"
Repairs leaks and defective portions of lined steel storage facilities	"	3	"
Repairs leaks and defective portions of wood storage facilities	"	3	"
Repairs leaks and defective portions of concrete storage facilities	"	3	"
Diagnoses cause of rust, corrosion, and leaks	"	3	"
Repairs and overhauls mixing and blending equipment and mechanical appurtenances:			
Troubleshoots and diagnoses malfunctions in mechanical systems	"	3	"

CHEMICAL ADDITION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Installs, removes, and replaces arms, paddles, and propellers	Mech Main	3	As Req
Disassembles and assembles mechanical drive systems	"	3	"
Inspects and measures gear drives for wear and defects	"	3	"
Inspects chain drives, replaces defective links, adjusts tension	"	3	"
Checks and measures sprocket alignment	"	3	"
Inspects sprocket teeth for wear, hooks, and other defects	"	3	"
Inspects and measures screen and bar rakes for wear and defects	"	3	"
Inspects and measures bearings and races for wear and defects	"	3	"
Cleans and finishes moving parts to prevent freezing or binding	"	3	"
Repacks bearings	"	3	"
Fits and replaces parts showing excessive wear or defects	"	3	"
Inspects and replaces water and oil seals as necessary	"	3	"
Dresses and reconditions scrapers, paddles, and propellers	"	3	"
Cleans and paints exposed surfaces	"	1	"
Replaces drive belts, pulleys, and tensioning devices	"	3	"

Note: Acids and alkalies used in this treatment are extremely hazardous

EQUALIZATION	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Operations			
Monitors and verifies proper operation and condition of the following units of equipment:			
Centrifugal, reciprocating, and diaphragm pumps	OP	2	1/Shift
Flow measuring devices and control instrumentation	"	2	"
Iron, steel, glass, copper, and PVC pipe and pipe fittings	"	2	"
Manual and automatic control valves	"	1	"
Steel, lined steel, wood, and concrete tanks, drums, and vessels	"	2	"
Belt, chain, and gear drive mechanisms	"	1	"
Electric motors, relays, and circuit breakers/switches	"	2	"
pH status instrumentation	"	2	"
Conductivity instrumentation	"	2	"
Reads and interprets status and control instrumentation:			
pH recorders and meters	"	2	"
Conductivity recorders and meters	"	2	"
Flow and level recorders and meters	"	2	"
Pilot lamps	"	2	"
Activates and controls units of equipment:			
Switches to standby or parallel pumps	"	2	As Req
Adjusts manual valves to control flow/retention time	"	3	"
Overrides automatic controls to correct in specific situations	"	3	"

EQUALIZATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Collects composite or grab samples for laboratory analysis	OP	2	As Req
Checks flow time for individual tanks using dye or salt solution	"	2	"
Preventive Maintenance Activities			
Services status and control instrumentation:			
Cleans and lubricates chart drive mechanisms		See Chem Add	
Cleans electrical sensors		"	
Checks electrical contacts, connections, and wiring		"	
Checks pneumatic sensors for leaks		"	
Checks zero or null setting on galvanometers and pen recorders		"	
Checks mechanical linkage for corrosion, rust, and freedom of movement		"	
Cleans indicator covers and glass viewing windows		"	
Cleans recorder pens and checks for ink flow		"	
Checks indicated values against known standards (checks calibration)		"	
Services electric motors and auxiliary equipment:			
Inspects motors for signs of overheating		"	
Checks for excessive vibration or hum		"	
Checks wiring insulation		"	
Checks for dirt or moisture		"	

EQUALIZATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks drive coupling and motor mounts for play/loose fittings		See Chem Add	
Checks for sticking brushes or excessive arcing		"	
Checks pilot lights and alarms		"	
Checks points and contacts for pitting		"	
Cleans and tightens electrical connections		"	
Checks and lubricates bearings		"	
Checks switches and circuit breakers for proper functioning		"	
Services centrifugal, reciprocating, and diaphragm pumps:			
Checks solenoid oiler flow; adjust as necessary		"	
Checks oil level in ball bearing housing; fills as necessary		"	
Checks grease cup; maintains proper pressure		"	
Checks enclosed shaft bearings; refills oil cup as necessary		"	
Checks ball-thrust bearings; adds fresh grease as necessary		"	
Checks guide bearings; adds grease as necessary		"	
Drains and adds fresh lubricant to shaft bearings		"	
Flushes bearing housing and adds fresh grease		"	
Checks bearing temperature; adjusts as necessary		"	
Checks stuffing boxes for leaks; tightens or repacks as necessary		"	
Checks water-seal systems for leaks; adjusts pressure as necessary		"	
Clean and paint pump casing		"	
Check, clean, lubricate, and adjust float switch system		"	

EQUALIZATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Inspect check valves for leaks		See Chem Add	
Clean sediment and accumulated solids from sumps		"	
Check and clean strainers		"	
Services flow measuring devices:			
Cleans and flushes annular chambers		"	
Cleans and flushes piezometer pressure taps		"	
Cleans and dresses orifice plates		"	
Cleans and paints exterior		"	
Inspects interior for corrosion		"	
Purges connecting lines and fittings		"	
Services pipes and pipe fittings:			
Checks for leaks in pipes and pipe fittings		"	
Inspects for rust and corrosion		"	
Cleans and paints pipes and fittings		"	
Flushes dead-ends		"	
Checks and cleans sediment traps		"	
Checks and cleans wells and sumps		"	
Mechanically cleans pipes with augers and snakes		"	
Services manual and automatic control valves:			
Checks valves for leaks		"	
Inspects for rust and corrosion		"	
Checks actuating bellows for leaks		"	
Checks linkages for free movement		"	
Checks for complete opening and closing		"	
Checks calibration		"	
Lubricates control linkage		"	
Adjusts packing		"	
Cleans and paints exterior		"	

EQUALIZATION (cont.)

	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Cleans solenoid actuating mechanisms	See Chem Add		
Services storage tanks, drums, and vessels:			
Checks for leaks		"	
Inspects for rust and corrosion		"	
Cleans and paints interior and exterior		"	
Removes accumulated deposits of sludge and sediment		"	
Services mechanical drive systems:			
Checks tension of flat and V-belt drives		"	
Checks and adjusts belt alignment		"	
Checks belts for wear		"	
Checks and adjusts chain drive slack		"	
Lubricates chain drive systems		"	
Checks lubricant levels in right-angle grear drives		"	
Checks lubricant levels in reduction gear boxes		"	
Drains and changes oil in sump systems		"	
Cleans and inspects variable speed belt drive systems		"	
Lubricates thrust and frame bearings for drive shafts		"	
Checks oil seals for leaks		"	
Lubricates pressure grease fittings		"	

Corrective Maintenance Activities

Repairs and overhauls status and control instrumentation:

EQUALIZATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Troubleshoots and diagnoses malfunctions in status and control instrumentation		See Chem Add	
Installs, removes, replaces status and control instrumentation		"	
Disassembles and reassembles status and control instrumentation		"	
Tests diaphragm, bourdon tubes, and bellows for leaks or defects		"	
Tests bimetallic strips and thermocouples for defects		"	
Tests electrical circuitry for shorts, open circuits, and resistance		"	
Cleans and adds mercury to manometers		"	
Cleans and sets contact points		"	
Cleans and checks knife edges		"	
Cleans and lubricates jeweled bearings		"	
Blows down pressure lines to remove restrictions or stoppages		"	
Cleans and checks orifices and nozzles		"	
Adjusts backlash in mechanical linkages		"	
Calibrates indicators and recorder pens against known standard		"	
Replaces worn or defective parts, seals, and bearings		"	
Repairs and overhauls electric motors and auxiliary equipment:			
Diagnoses and troubleshoots electrical malfunctions		"	
Installs, removes, replaces electric motors, wiring, and control devices		"	

EQUALIZATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Inspects and tests rotor and stator windings for shorts or open circuits		See Chem Add	
Inspects commutator for wear, shorts, and signs of excessive heat		"	
Checks brushes for wear and proper spring tension		"	
Adjusts brushes to seat properly and prevent sticking		"	
Cleans, adjusts, and lubricates bearings		"	
Checks thermal switches, circuit breakers, and fuses		"	
Cleans and polishes collector rings		"	
Checks and tightens pigtails and mechanical wire connections		"	
Replaces or repairs defective parts in motors and control devices		"	
Adjusts rotor and shaft alignment		"	
Reconditions or replaces contacts on relays and switches		"	
Replaces defective wiring and conduit		"	
Inspects exposed equipment for defective gaskets and seals		"	
Measures voltage, current, and power consumption		"	
Checks motor speeds		"	
Repairs and overhauls centrifugal, reciprocating, and diaphragm pumps:			
Troubleshoots and diagnoses malfunctions in pumps		"	
Installs, removes, and replaces pumps		"	

EQUALIZATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Disassembles and assembles pumps		See Chem Add	
Inspects and measures bearings and bearing races for defects		"	
Repacks ball-thrust bearings, roller bearings, and guide bearings		"	
Cleans and inspects pump interior		"	
Checks stuffing box for free movement of gland and excessive leakage		"	
Repacks gland assembly and adjusts		"	
Grinds and laps valves and valve seats		"	
Inspects impellers for deposits, scaling, and cavitation pits		"	
Dynamically balances impellers		"	
Checks and aligns drive system		"	
Fits replacement parts		"	
Repairs bent float rods, binding mechanical fittings		"	
Lubricates mechanical fittings		"	
Cleans and paints exterior housing		"	
Repairs and replaces pipes and pipe fittings:			
Troubleshoots and diagnoses nature and location of stoppages		"	
Removes and replaces sections of pipe, pipe fittings, and couplings		"	
Cuts and threads pipe		"	
Cleans pipe using mechanical and hydraulically propelled tools		"	
Replaces gaskets and seals on flange type joints		"	
Bends pipe and tubing			

EQUALIZATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Tests pipe systems for pressure capability and leaks		See Chem Add	
May be required to repair and replace special purpose pipe and fittings of the following types:			
Glass		"	
Glass or plastic lined steel		"	
Plastic and PVC		"	
Aluminum		"	
Wood		"	
Vitrified tile		"	
Repairs and overhauls manual and automatic control valves:			
Troubleshoots and diagnoses malfunctions in manual and controlled valves		"	
Installs, removes, and replaces valves		"	
Assembles and disassembles valves and control mechanisms		"	
Inspects and measures valve clearances		"	
Grinds, polishes, laps-in valves and valve seats		"	
Cleans and inspects valve actuating mechanisms		"	
Adjusts backlash in valve actuating mechanisms		"	
Lubricates valve actuating mechanisms		"	
Tests bellows and diaphragm actuators for leaks		"	
Calibrates valve position and control actuator		"	
Adjusts and replaces packing and seals		"	
Tests valves for complete opening and shut-off		"	

EQUALIZATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Tests functioning of control actuators (pneumatic, hydraulic, electrical, mechanical)		See Chem Add	
Replaces worn or defective valve and actuator parts		"	
Repairs and overhauls storage tanks, drums, and vessels:			
Repairs leaks and defective portions of steel storage facilities		"	
Repairs leaks and defective portions of lined steel storage facilities		"	
Repairs leaks and defective portions of wood storage facilities		"	
Repairs leaks and defective portions of concrete storage facilities		"	
Diagnoses cause of rust, corrosion, and leaks		"	

OIL REMOVAL	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Operations			
Monitors and verifies proper operation and condition of the following units of equipment:			
Pressure floatation units/preaerators	OP	2	1/Shift
Vacuum floatation units/preaerators	"	2	"
Gravity separation unit	"	2	"
Compressors or vacuum pumps	"	2	"
Centrifugal, reciprocating, and diaphragm pumps	"	2	"
Pressure and vacuum monitoring and control equipment	"	2	"
Flow measuring devices	"	2	"
Manual and automatic control valves	"	2	"
Iron, steel, and plastic pipe and pipe fittings	"	1	"
Steel tanks, drums, and vessels	"	1	"
Belt, chain, and gear drive mechanisms	"	2	"
Reads and interprets status and control instrumentation of the following types:			
Flow recorders and meters	"	2	"
Level indicators	"	2	"
Pressure indicators and recorders	"	2	"
Pilot lamps and voltage/current recorders and indicators	"	2	"
Activates and controls units of equipment:			
Adjusts manual valves to achieve specified flow, pressure, and retention time	"	3	"
Switches to standby or parallel pumps	"	2	"
Overrides automatic controls to correct in specific situations	"	3	"

OIL REMOVAL (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Activates collectors and skimmers on intermittent basis or continuously	OP	2	1/Shift
Removes and disposes of oil and floatable solids:			
Withdraws skimmings from storage unit as necessary	"	1	As Req
Removes skimmings from discharge weirs	"	1	"
Stores skimmings for disposal or disposes of skimmings	"	1	"
Collects composite or grab samples of skimmings, influent, and effluent for laboratory analysis	"	2	1/Shift
Preventive Maintenance Activities			
Services pressure and vacuum separation units:			
Checks for pressure or vacuum leaks	"	2	"
Inspects for rust and corrosion	"	2	"
Drains and cleans interior, flushes sediment, removes accumulated grit	"	2	"
Services air compressors and vacuum pumps:			
Checks on-off thresholds	"	2	"
Cleans or changes air filters	"	2	As Req
Drains condensate from pressure storage tanks	"	2	wkly
Checks oil level in crank cases and sumps, adds oil as required	"	2	dly
Drains and refills oil reservoirs	"	2	mthly
Checks valves for leaks	"	2	dly
Checks for overheating	"	2	1/Shift

OIL REMOVAL (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Services status and control instrumentation:			
Cleans and lubricates chart drive mechanisms		See Chem Add	
Cleans electrical sensors		"	
Checks electrical contacts, connections, and wiring		"	
Checks pneumatic sensors for leaks		"	
Checks zero or null setting on galvanometers and pen recorders		"	
Checks mechanical linkage for corrosion, rust, and freedom of movement		"	
Cleans indicator covers and glass viewing windows		"	
Cleans recorder pens and checks for ink flow		"	
Checks indicated values against known standards (checks calibration)		"	
Services electric motors and auxiliary equipment:			
Inspects motors for signs of overheating		"	
Checks for excessive vibration or hum		"	
Checks wiring insulation		"	
Checks for dirt or moisture		"	
Checks drive coupling and motor mounts for play/loose fittings		"	
Checks for sticking brushes or excessive arcing		"	
Checks pilot lights and alarms		"	
Checks points and contacts for pitting		"	
Cleans and tightens electrical connections		"	
Checks and lubricates bearings		"	
Checks switches and circuit breakers for proper functioning		"	

OIL REMOVAL (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Services storage tanks, drums, and vessels:			
Checks for leaks		See Chem Add	
Inspects for rust and corrosion		"	
Cleans and paints interior and exterior		"	
Removes accumulated deposits of sludge and sediment		"	
Services mechanical drive systems:			
Checks tension of flat and V-belt drives		"	
Checks and adjusts belt alignment		"	
Checks belts for wear		"	
Checks and adjusts chain drive slack		"	
Lubricates chain drive systems		"	
Checks lubricant levels in right-angle gear drives		"	
Checks lubricant levels in reduction gear boxes		"	
Drains and changes oil in sump systems		"	
Cleans and inspects variable speed belt drive systems		"	
Lubricates thrust and frame bearings for drive shafts		"	
Checks oil seals for leaks		"	
Lubricates pressure grease fittings		"	

Corrective Maintenance Activities

Repairs and overhauls air compressors and vacuum pumps:

OIL REMOVAL (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Troubleshoots and diagnoses malfunctions in compressors and vacuum pumps		See Chem Add	
Installs, removes, and replaces compressors and vacuum pumps		"	
Disassembles and assembles compressors and vacuum pumps		"	
Inspects and measures bearings and bearing races for defects		"	
Repacks ball-thrust bearings, roller bearings, and guide bearings		"	
Cleans and inspects pump and compressor interior		"	
Grinds and laps valves and valve seats		"	
Fits replacement parts, seals, and gaskets		"	
Inspects diaphragms for defects and serviceability		"	
Lubricates mechanical fittings		"	
Cleans and paints exterior housing		"	
Tests and certifies pressure ratings		"	
Services centrifugal, reciprocating, and diaphragm pumps:			
Checks solenoid oiler flow; adjusts as necessary		"	
Checks oil level in ball bearing housing; fills as necessary		"	
Checks grease cup; maintains proper pressure		"	
Checks enclosed shaft bearings; refills oil cup as necessary		"	
Checks ball-thrust bearings; adds fresh grease as necessary		"	
Checks guide bearings; adds grease as necessary		"	

OIL REMOVAL (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Drains and adds fresh lubricant to shaft bearings		See Chem Add	
Flushes bearing housing and adds fresh grease		"	
Checks bearing temperatures; adjusts as necessary		"	
Checks stuffing boxes for leaks; tightens or repacks as necessary		"	
Checks water-seal systems for leaks; adjusts pressure as necessary		"	
Clean and paint pump casing		"	
Check, clean, lubricate, and adjust float switch system		"	
Inspect check valves for leaks		"	
Clean sediment and accumulated solids from sumps		"	
Check and clean strainers		"	
Services flow measuring devices:			
Cleans and flushes annular chambers		"	
Cleans and flushes piezometer pressure taps		"	
Cleans and dresses orifice plates		"	
Cleans and paints exterior		"	
Inspects interior for corrosion		"	
Purges connecting lines and fittings		"	
Services pipes and pipe fittings:			
Checks for leaks in pipes and pipe fittings		"	
Inspects for rust and corrosion		"	
Cleans and paints pipes and fittings		"	
Flushes dead-ends		"	
Checks and cleans sediment traps		"	

OIL REMOVAL (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks and cleans wells and sumps		See Chem Add	
Mechanically cleans pipes with augers and snakes		"	
Services manual and automatic control valves:			
Checks valves for leaks		"	
Inspects for rust and corrosion		"	
Checks actuating bellows for leaks		"	
Checks linkages for free movement		"	
Checks for complete opening and closing		"	
Checks calibration		"	
Lubricates control linkage		"	
Adjusts packing		"	
Cleans and paints exterior		"	
Cleans solenoid actuating mechanisms		"	
Repairs and overhauls status and control instrumentation:			
Troubleshoots and diagnoses malfunctions in status and control instrumentation		"	
Installs, removes, replaces status and control instrumentation		"	
Disassembles and reassembles status and control instrumentation		"	
Tests diaphragms, bourdon tubes, and bellows for leaks or defects		"	
Tests bimetallic strips and thermocouples for defects		"	
Tests electrical circuitry for shorts, open circuits, and resistance		"	
Cleans and adds mercury to manometers		"	

OIL REMOVAL (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Cleans and sets contact points		See Chem Add	
Cleans and checks knife edges		"	
Cleans and lubricates jeweled bearings		"	
Blows down pressure lines to remove restrictions or stoppages		"	
Cleans and checks orifices and nozzles		"	
Adjusts backlash in mechanical linkages		"	
Calibrates indicators and recorder pens against known standard		"	
Replaces worn or defective parts, seals, and bearings		"	
Repairs and overhauls electric motors and auxiliary equipment:			
Diagnoses and troubleshoots electrical malfunctions		"	
Installs, removes, replaces electric motors, wiring, and control devices		"	
Inspects and tests rotor and stator windings for shorts or open circuits		"	
Inspects commutator for wear, shorts, and signs of excessive heat		"	
Checks brushes for wear and proper spring tension		"	
Adjusts brushes to seat properly and prevent sticking		"	
Cleans, adjusts, and lubricates bearings		"	
Checks thermal switches, circuit breakers, and fuses		"	
Cleans and polishes collector rings		"	
Checks and tightens pigtails and mechanical wire connections		"	

OIL REMOVAL (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Replaces or repairs defective parts in motors and control devices		See Chem Add	
Adjusts rotor and shaft alignment		"	
Reconditions or replaces contacts on relays and switches		"	
Replaces defective wiring and conduit		"	
Inspects exposed equipment for defective gaskets and seals		"	
Measures voltage, current, and power consumption		"	
Checks motor speeds		"	
Repairs and overhauls centrifugal, reciprocating, and diaphragm pumps:			
Troubleshoots and diagnoses malfunctions in pumps		"	
Installs, removes, and replaces pumps		"	
Disassembles and assembles pumps		"	
Inspects and measures bearings and bearing races for defects		"	
Repacks ball-thrust bearings, roller bearings, and guide bearings		"	
Cleans and inspects pump interior		"	
Checks stuffing box for free movement of gland and excessive leakage		"	
Repacks gland assembly and adjusts		"	
Grinds and laps valves and valve seats		"	
Inspects impellers for deposits, scaling, and cavitation pits		"	
Dynamically balances impellers		"	
Checks and aligns drive system		"	

OIL REMOVAL (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Fits replacement parts		See Chem Add	
Repairs bent float rods, binding mechanical		"	
fittings		"	
Lubricates mechanical fittings		"	
Cleans and paints exterior housing			
Repairs and replaces pipes and pipe fittings:			
Troubleshoots and diagnoses nature and location of stoppages		"	
Removes and replaces sections of pipe, pipe		"	
fittings, and couplings		"	
Cuts and threads pipe			
Cleans pipe using mechanical and hydraulically propelled tools		"	
Replaces gaskets and seals on flange type		"	
joints		"	
Bends pipe and tubing			
Tests pipe systems for pressure capability and leaks		"	
May be required to repair and replace special purpose pipe and fittings of the following types:		"	
Glass		"	
Glass or plastic lined steel		"	
Plastic and PVC		"	
Aluminum		"	
Wood		"	
Vitrified tile			

OIL REMOVAL (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repairs and overhauls manual and automatic control valves:			
Troubleshoots and diagnoses malfunction in manual and controlled valves		See Chem Add	
Installs, removes, and replaces valves		"	
Assembles and disassembles valves and control mechanisms		"	
Inspects and measures valve clearances		"	
Grinds, polishes, laps in valves and valve seats		"	
Cleans and inspects valve actuating mechanisms		"	
Adjusts backlash in valve actuating mechanisms		"	
Lubricates valve actuating mechanisms		"	
Tests bellows and diaphragm actuators for leaks		"	
Calibrates valve position and control actuator		"	
Adjusts and replaces packing and seals		"	
Tests valves for complete opening and shut-off		"	
Tests functioning of control actuators (pneumatic, hydraulic, electrical, mechanical)		"	
Replaces worn or defective valve and actuator parts		"	
Repairs and overhauls storage tanks, drums, and vessels:			
Repairs leaks and defective portions of steel storage facilities		"	
Repairs leaks and defective portions of lined steel storage facilities		"	
Repairs leaks and defective portions of wood storage facilities		"	

OIL REMOVAL (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repairs leaks and defective portions of concrete storage facilities		See Chem Add	
Diagnoses cause of rust, corrosion, and leaks		"	
Repairs and overhauls mixing and blending equipment and mechanical appurtenances:			
Troubleshoots and diagnoses malfunctions in mechanical systems		"	
Installs, removes, and replaces arms, paddles, and propellers		"	
Disassembles and assembles mechanical drive systems		"	
Inspects and measures gear drives for wear and defects		"	
Inspects chain drives, replaces defective links, adjusts tension		"	
Checks and measures sprocket alignment		"	
Inspects sprocket teeth for wear, hooks, and other defects		"	
Inspects and measures screen and bar rakes for wear and defects		"	
Inspects and measures bearings and races for wear and defects		"	
Cleans and finishes moving parts to prevent freezing or binding		"	
Repacks bearings		"	
Fits and replaces parts showing excessive wear or defects		"	
Inspects and replaces water and oil seals as necessary		"	

OIL REMOVAL (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Dresses and reconditions scrapers, paddles, and propellers		See Chem Add	
Cleans and paints exposed surfaces		"	
Replaces drive belts, pulleys, and tensioning devices		"	

SEDIMENTATION	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Operations			
Monitors and verifies proper operation and condition of the following units of equipment:			
Mechanically cleaned sedimentation tanks	OP	2	1/Shift
Manually cleaned sedimentation tanks	"	2	"
Centrifugal, reciprocating, and diaphragm pumps	"	2	"
Flow measuring devices	"	2	"
Pipe and pipe fittings	"	1	"
Manual and automatic control valves	"	2	"
Steel, wood, and concrete tanks	"	1	"
Electric motors, relays, and circuit breakers/ switches	"	2	"
Mixing and blending equipment	"	2	"
Belt, chain, and gear drive mechanisms	"	2	"
Reads and interprets status and control instrumentation:			
Flow meters and recorders	"	2	"
Level indicators	"	2	"
Pilot lamps and voltage/current recorders and meters	"	2	"
Collects and labels composite or grab samples for laboratory analysis	"	2	"
Activates and controls units of equipment:			
Adjusts manual valves to achieve specified flow, pressure and retention times	"	2	As Req
Switches to standby or parallel pumps	"	2	"

SEDIMENTATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Overrides automatic controls to correct in specific situations	OP	3	As Req
Activates and adjusts mechanical sedimentation and scum removal equipment	"	2	"
Adjusts distribution of flow in tank	"	3	"
Adjusts mechanical flocculation equipment	"	3	"
Removes and disposes of sludge and grit:			
Scrapes and removes skimmings from weir	"	1	dly
Cleans grit chambers	"	1	dly
Dewaters and cleans tank and sludge withdrawl equipment	"	2	mthly
Empties sludge collecting tanks and disposes of sludge	"	1	dly
Preventive Maintenance Activities			
Services status and control instrumentation:			
Cleans and lubricates chart drive mechanisms	"	2	2/yr
Cleans electrical sensors	"	2	mthly
Checks electrical contacts, connections, and wiring	"	2	wkly
Checks pneumatic sensors for leaks	"	2	wkly
Checks zero or null setting on galvanometers and pen recorders	"	2	wkly
Checks mechanical linkage for corrosion, rust, and freedom of movement	"	2	mthly
Cleans indicator covers and glass viewing windows	"	2	mthly
Cleans recorder pens and checks for ink flow	"	2	dly

SEDIMENTATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks indicated values against known standards (checks calibration)	OP	3	mthly
Services electric motors and auxiliary equipment:			
Inspects motors for signs of overheating		See Chem Add	
Checks for excessive vibration or hum		"	
Checks wiring insulation		"	
Checks for dirt or moisture		"	
Checks drive coupling and motor mounts for play/loose fittings		"	
Checks for sticking brushes or excessive arcing		"	
Checks pilot lights and alarms		"	
Checks points and contacts for pitting		"	
Cleans and tightens electrical connections		"	
Checks and lubricates bearings		"	
Checks switches and circuit breakers for proper functioning		"	
Services centrifugal, reciprocating, and diaphragm pumps:			
Checks solenoid oiler flow; adjusts as necessary		"	
Checks oil level in ball bearing housing; fills as necessary		"	
Checks grease cup; maintains proper pressure		"	
Checks enclosed shaft bearings; refills oil cup as necessary		"	
Checks ball-thrust bearings; adds fresh grease as necessary		"	
Checks guide bearings; adds grease as necessary		"	
Drains and adds fresh lubricant to shaft bearings		"	

SEDIMENTATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Flushes bearing housing and adds fresh grease	See Chem Add		
Checks bearing temperatures; adjusts as necessary		"	
Checks stuffing boxes for leaks; tightens or repacks as necessary		"	
Checks water-seal systems for leaks; adjusts pressure as necessary		"	
Clean and paint pump casing		"	
Check, clean, lubricate, and adjust float switch system		"	
Inspect check valves for leaks		"	
Clean sediment and accumulated solids from sumps		"	
Check and clean strainers		"	
Services flow measuring devices:			
Cleans and flushes annular chambers		"	
Cleans and flushes piezometer pressure taps		"	
Cleans and dresses orifice plates		"	
Cleans and paints exterior		"	
Inspects interior for corrosion		"	
Purges connecting lines and fittings		"	
Services pipes and pipe fittings:			
Checks for leaks in pipes and pipe fittings		"	
Inspects for rust and corrosion		"	
Cleans and paints pipes and fittings		"	
Flushes dead-ends		"	
Checks and cleans sediment traps		"	
Checks and cleans wells and sumps		"	
Mechanically cleans pipes with augers and snakes		"	

SEDIMENTATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Services manual and automatic control valves:			
Checks valves for leaks		See Chem Add	
Inspects for rust and corrosion		"	
Checks actuating bellows for leaks		"	
Checks linkages for free movement		"	
Checks for complete opening and closing		"	
Checks calibration		"	
Lubricates control linkage		"	
Adjusts packing		"	
Cleans and paints exterior		"	
Cleans solenoid actuating mechanisms		"	
Services storage tanks, drums, and vessels:			
Checks for leaks		"	
Inspects for rust and corrosion		"	
Cleans and paints interior and exterior		"	
Removes accumulated deposits of sludge and sediment		"	
Services mixing and blending equipment:			
Cleans deposits from paddles, arms and propellers		"	
Inspects for rust and corrosion		"	
Inspects mechanical drive functioning		"	
Lubricates mechanical drive system		"	
Paints and protects exposed surfaces		"	
Checks for homogeneity of mixed substances		"	
Checks speed of mixing or blending		"	
Services mechanical drive systems:			
Checks tension of flat and V-belt drives		"	

SEDIMENTATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks and adjusts belt alignment		See Chem Add	
Checks belts for wear		"	
Checks and adjusts chain drive slack		"	
Lubricates chain drive systems		"	
Checks lubricant levels in right-angle gear drives		"	
Checks lubricant levels in reduction gear boxes		"	
Drains and changes oil in sump systems		"	
Cleans and inspects variable speed belt drive systems		"	
Lubricates thrust and frame bearings for drive shafts		"	
Checks oil seals for leaks		"	
Lubricates pressure grease fittings		"	
Corrective Maintenance Activities			
Repairs and overhauls status and control instrumentation:			
Troubleshoots and diagnoses malfunctions in status and control instrumentation		"	
Installs, removes, replaces status and control instrumentation		"	
Disassembles and reassembles status and control instrumentation		"	
Tests diaphragms, bourdon tubes, and bellows for leaks or defects		"	
Tests bimetallic strips and thermocouples for defects		"	

SEDIMENTATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Tests electrical circuitry for shorts, open circuits, and resistance	See Chem Add		
Cleans and adds mercury to manometers		"	
Cleans and sets contact points		"	
Cleans and checks knife edges		"	
Cleans and lubricates jeweled bearings		"	
Blows down pressure lines to remove restrictions or stoppages		"	
Cleans and checks orifices and nozzles		"	
Adjusts backlash in mechanical linkages		"	
Calibrates indicators and recorder pens against known standard		"	
Replaces worn or defective parts, seals, and bearings		"	
Repairs and overhauls electric motors and auxiliary equipment:			
Diagnoses and troubleshoots electrical malfunctions		"	
Installs, removes, replaces electric motors, wiring, and control devices		"	
Inspects and tests rotor and stator windings for shorts or open circuits		"	
Inspects commutator for wear, shorts, and signs of excessive heat		"	
Checks brushes for wear and proper spring tension		"	
Adjusts brushes to seat properly and prevent sticking		"	
Cleans, adjusts, and lubricates bearings		"	

SEDIMENTATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks thermal switches, circuit breakers, and fuses		See Chem Add	
Cleans and polishes collector rings		"	
Checks and tightens pigtails and mechanical wire connections		"	
Replaces or repairs defective parts in motors and control devices		"	
Adjusts rotor and shaft alignment		"	
Reconditions or replaces contacts or relays and switches		"	
Replaces defective wiring and conduit		"	
Inspects exposed equipment for defective gaskets and seals		"	
Measures voltage, current, and power consumption		"	
Checks motor speeds		"	
Repairs and overhauls centrifugal, reciprocating, and diaphragm pumps:			
Troubleshoots and diagnoses malfunctions in pumps		"	
Installs, removes, and replaces pumps		"	
Disassembles and assembles pumps		"	
Inspects and measures bearings and bearing races for defects		"	
Repacks ball-thrust bearings, roller bearings, and guide bearings		"	
Cleans and inspects pump interior		"	
Checks stuffing box for free movement of gland and excessive leakage		"	
Repacks gland assembly and adjusts		"	

SEDIMENTATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Grinds and laps valves and valve seats		See Chem Add	
Inspects impellers for deposits, scaling, and cavitation pits		"	
Dynamically balances impellers		"	
Checks and aligns drive system		"	
Fits replacement parts		"	
Repairs bent float rods, binding mechanical fittings		"	
Lubricates mechanical fittings		"	
Cleans and paints exterior housing		"	
Repairs and replaces pipes and pipe fittings:			
Troubleshoots and diagnoses nature and location of stoppages		"	
Removes and replaces sections of pipe, pipe fittings, and couplings		"	
Cuts and threads pipe		"	
Cleans pipe using mechanical and hydraulically propelled tools		"	
Replaces gaskets and seals on flange type joints		"	
Bends pipe and tubing		"	
Tests pipe systems for pressure capability and leaks		"	
May be required to repair and replace special purpose pipe and fittings of the following types:			
Glass		"	
Glass or plastic lined steel		"	
Plastic and PVC		"	

SEDIMENTATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Aluminum		See Chem Add	
Wood		"	
Vitrified tile		"	
Repairs and overhauls manual and automatic control valves:			
Troubleshoots and diagnoses malfunction in manual and controlled valves		"	
Installs, removes, and replaces valves		"	
Assembles and disassembles valves and control mechanisms		"	
Inspects and measures valve clearances		"	
Grinds, polishes, laps in valves and valve seats		"	
Cleans and inspects valve actuating mechanisms		"	
Adjusts backlash in valve actuating mechanisms		"	
Lubricates valve actuating mechanisms		"	
Tests bellows and diaphragm actuators for leaks		"	
Calibrates valve position and control actuator		"	
Adjusts and replaces packing and seals		"	
Tests valves for complete opening and shut-off		"	
Tests functioning of control actuators (pneumatic, hydraulic, electrical, mechanical)		"	
Replaces worn or defective valve and actuator parts		"	
Repairs and overhauls storage tanks, drums and vessels:			
Repairs leaks and defective portions of steel storage facilities		"	

SEDIMENTATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repairs leaks and defective portions of lined steel storage facilities		See Chem Add	
Repairs leaks and defective portions of wood storage facilities		"	
Repairs leaks and defective portions of concrete storage facilities		"	
Diagnoses cause of rust, corrosion, and leaks		"	
Repairs and overhauls mixing and blending equipment and mechanical appurtenances:			
Troubleshoots and diagnoses malfunctions in mechanical systems		"	
Installs, removes, and replaces arms, paddles, and propellers		"	
Disassembles and assembles mechanical drive systems		"	
Inspects and measures gear drives for wear and defects		"	
Inspects chain drives, replaces defective links, adjusts tension		"	
Checks and measures sprocket alignment		"	
Inspects sprocket teeth for wear, hooks, and other defects		"	
Inspects and measures screen and bar rakes for wear and defects		"	
Inspects and measures bearings and races for wear and defects		"	
Cleans and finishes moving parts to prevent freezing or binding		"	
Repacks bearings		"	
Fits and replaces parts showing excessive wear or defects		"	

SEDIMENTATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Inspects and replaces water and oil seals as necessary		See Chem Add	
Dresses and reconditions scrapers, paddles, and propellers		"	
Cleans and paints exposed surfaces		"	
Replaces drive belts, pulleys, and tensioning devices		"	

FILTRATION	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Operations			
Monitors and verifies proper operation and condition of the following units of equipment:			
Diatomaceous earth filters	OP	2	1/Shift
Rapid sand filters	"	2	"
Rotary vacuum filtration units	"	2	"
Plate and frame filters	"	2	"
Electric motors, relays, and circuit breakers/ switches	"	2	"
Centrifugal, reciprocating, and diaphragm pumps	"	2	"
Flow measuring devices	"	2	"
Pipe and pipe fittings	"	2	"
Manual and automatic control valves	"	2	"
Steel tanks, drums, and vessels	"	1	"
Air compressors and vacuum pumps	"	2	"
Reads and interprets status and control instrumentation:			
Sight windows	"	2	"
Level indicators	"	2	"
Flow meters and recorders	"	2	"
Pilot lamps	"	2	"
Activates and controls units of equipment:			
Adjusts manual valves to achieve specified influent level	"	3	"
Opens and closes manual valves to perform backwashing	"	2	"
Controls rate of backwash	"	2	"
Activates and controls influent and effluent pumps	"	2	"

FILTRATION (cont.)

	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Overrides automatic controls to correct in specific situations	OP	3	1/Shift
Activates and controls vacuum pumps and air compressors	"	2	"
Adjusts dosage frequency on intermittent sand filters	"	2	"
Adjusts and sets rate controller according to suspended solids in influent	"	3	"
Removes and disposes of backwash sludge and grit:			
Preventive Maintenance Activities			
Services diatomaceous earth filtration units:			
Cleans and flushes grease and slime from dosing tanks	"	2	"
Checks distributors for plugging	"	2	"
Checks and adjusts for even distribution of influent	"	3	"
Checks for ponding, insects, odors, and icing	"	2	"
Checks for rust and corrosion	"	2	wkly
Cleans and paints exposed surfaces	"	1	yrly
Checks water distribution system for clogging	"	2	1/Shift
Services rapid sand filters:			
Cleans and flushes backwash weirs	"	2	As Req
Checks condition of filter bed for cracks, clogging, mounds, and craters	"	2	2/Shift
Cleans and inspects underdrain system	"	2	wkly
Rakes and screens filter bed	"	2	wkly

FILTRATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Surface scours filter bed	OP	2	wkly
Cleans filter bed through chemical addition	"	2	"
Checks for rust and corrosion	"	2	"
Checks water distribution system for clogging	"	2	"
Services plate and frame filters:			
Checks and adjusts tension on frame mountings	"	2	1/Shift
Checks for rust and corrosion	"	2	wkly
Cleans and paints exterior	"	2	yrly
Services status and control instrumentation:			
Cleans and lubricates chart drive mechanisms	"	2	2/yr
Cleans electrical sensors	"	2	mthly
Checks electrical contacts, connections, and wiring	"	2	wkly
Checks pneumatic sensors for leaks	"	2	"
Checks zero or null setting on galvanometers and pen recorders	"	2	"
Checks mechanical linkage for corrosion, rust, and freedom of movement	"	2	"
Cleans indicator covers and glass viewing windows	"	2	mthly
Cleans recorder pens and checks for ink flow	"	2	dly
Checks indicated values against known standards (checks calibration)	"	2	mthly
Services electric motors and auxiliary equipment:			
Inspects motors for signs of overheating		See Chem Add	
Checks for excessive vibration or hum		"	
Checks wiring insulation		"	
Checks for dirt or moisture		"	

FILTRATION (cont.)

	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks drive coupling and motor mounts for play/loose fittings		See Chem Add	
Checks for sticking brushes or excessive arcing		"	
Checks pilot lights and alarms		"	
Checks points and contacts for pitting		"	
Cleans and tightens electrical connections		"	
Checks and lubricates bearings		"	
Checks switches and circuit breakers for proper functioning		"	
Services centrifugal, reciprocating, and diaphragm pumps:			
Checks solenoid oiler flow; adjusts as necessary		"	
Checks oil level in ball bearing housing; fills as necessary		"	
Checks grease cup; maintains proper pressure		"	
Checks enclosed shaft bearings; refills oil cup as necessary		"	
Checks ball-thrust bearings; adds fresh grease as necessary		"	
Checks guide bearings; adds grease as necessary		"	
Drains and adds fresh lubricant to shaft bearings		"	
Flushes bearing housing and adds fresh grease		"	
Checks bearing temperatures; adjusts as necessary		"	
Checks stuffing boxes for leaks; tightens or repacks as necessary		"	
Checks water-seal systems for leaks, adjusts pressure as necessary		"	
Clean and paint pump casing		"	

FILTRATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Check, clean, lubricate, and adjust float switch system		See Chem Add	
Inspect check valves for leaks		"	
Clean sediment and accumulated solids from sumps		"	
Check and clean strainers		"	
Services flow measuring devices:			
Cleans and flushes annular chambers		"	
Cleans and flushes piezometer pressure taps		"	
Cleans and dresses orifice plates		"	
Cleans and paints exterior		"	
Inspects interior for corrosion		"	
Purges connecting lines and fittings		"	
Services pipes and pipe fittings:			
Checks for leaks in pipes and pipe fittings		"	
Inspects for rust and corrosion		"	
Cleans and paints pipes and fittings		"	
Flushes dead-ends		"	
Checks and cleans sediment traps		"	
Checks and cleans wells and sumps		"	
Mechanically cleans pipes with augers and snakes		"	
Services manual and automatic control valves:			
Checks valves for leaks		"	
Inspects for rust and corrosion		"	
Checks actuating bellows for leaks		"	
Checks linkages for free movement		"	
Checks for complete opening and closing		"	
Checks calibration		"	

FILTRATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Lubricates control linkage		See Chem Add	
Adjusts packing		"	
Cleans and paints exterior		"	
Cleans solenoid actuating mechanisms		"	
Services storage tanks, drums, and vessels:			
Checks for leaks		"	
Inspects for rust and corrosion		"	
Cleans and paints interior and exterior		"	
Removes accumulated deposits of sludge and sediment		"	
Corrective Maintenance Activities			
Repairs and overhauls diatomaceous earth filtration units:			
Drains and inspects filter bed and underdrain system		"	
Removes sediment cake and sludge		"	
Replaces filter bed		"	
Cleans and replaces underdrain system		"	
Repairs leaks		"	
Troubleshoots and diagnoses malfunctions in slow sand filters		"	
Cleans and unclogs water distribtuion system		"	
Repairs and overhauls rapid sand filters:			
Troubleshoots and diagnoses malfunctions in rapid sand filters		"	

FILTRATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Drains filter and inspects composition of filter bed		See Chem Add	
Removes filter bed materials and replaces		"	
Cleans and replaces backwash system		"	
Repairs and overhauls plate and frame filters:			
Troubleshoots and diagnoses malfunctions in plate and frame filters		"	
Disassembles and assembles plate and frame filters		"	
Inspects filter frames for clogging or other defects		"	
Inspects gaskets and seals for defects and serviceability		"	
Cleans or replaces filters, gaskets, and seals		"	
Repairs and overhauls status and control instrumentation:			
Troubleshoots and diagnoses malfunctions in status and control instrumentation		"	
Installs, removes, replaces status and control instrumentation		"	
Disassembles and reassembles status and control instrumentation		"	
Tests diaphragms, bourdon tubes, and bellows for leaks or defects		"	
Tests bimetallic strips and thermocouples for defects		"	
Tests electrical circuitry for shorts, open circuits, and resistance		"	
Cleans and adds mercury to manometers		"	

FILTRATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Cleans and sets contact points		See Chem Add	
Cleans and checks knife edges		"	
Cleans and lubricates jeweled bearings		"	
Blows down pressure lines to remove restrictions or stoppages		"	
Cleans and checks orifices and nozzles		"	
Adjusts backlash in mechanical linkages		"	
Calibrates indicators and recorder pens against known standard		"	
Replaces worn or defective parts, seals, and bearings		"	
Repairs and overhauls electric motors and auxiliary equipment:			
Diagnoses and troubleshoots electrical malfunctions		"	
Installs, removes, replaces electric motors, wiring, and control devices		"	
Inspects and tests rotor and stator windings for shorts or open circuits		"	
Inspects commutator for wear, shorts, and signs of excessive heat		"	
Checks brushes for wear and proper spring tension		"	
Adjusts brushes to seat properly and prevent sticking		"	
Cleans, adjusts, and lubricates bearings		"	
Checks thermal switches, circuit breakers, and fuses		"	
Cleans and polishes collector rings		"	

FILTRATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks and tightens pigtails and mechanical wire connections		See Chem Add	
Replaces or repairs defective parts in motors and control devices		"	
Adjusts rotor and shaft alignment		"	
Reconditions or replaces contacts on relays and switches		"	
Replaces defective wiring and conduit		"	
Inspects exposed equipment for defective gaskets and seals		"	
Measures voltage, current, and power consumption		"	
Checks motor speeds		"	
Repairs and overhauls centrifugal, reciprocating, and diaphragm pumps:			
Troubleshoots and diagnoses malfunctions in pumps		"	
Installs, removes, and replaces pumps		"	
Disassembles and assembles pumps		"	
Inspects and measures bearings and bearing races for defects		"	
Repacks ball-thrust bearings, roller bearings, and guide bearings		"	
Cleans and inspects pump interior		"	
Checks stuffing box for free movement of gland and excessive leakage		"	
Repacks gland assembly and adjusts		"	
Grinds and laps valves and valve seats		"	
Inspects impellers for deposits, scaling, and cavitation pits		"	

FILTRATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Dynamically balances impellers		See Chem Add	
Checks and aligns drive system		"	
Fits replacement parts		"	
Repairs bent float rods, binding mechanical fittings		"	
Lubricates mechanical fittings		"	
Cleans and paints exterior housing		"	
Repairs and replaces pipes and pipe fittings:			
Troubleshoots and diagnoses nature and location of stoppages		"	
Removes and replaces sections of pipe, pipe fittings, and couplings		"	
Cuts and threads pipe		"	
Cleans pipe using mechanical and hydraulically propelled tools		"	
Replaces gaskets and seals on flange type joints		"	
Bends pipe and tubing		"	
Tests pipe systems for pressure capability and leaks		"	
May be required to repair and replace special purpose pipe and fittings of the following types:			
Glass		"	
Glass or plastic lined steel		"	
Plastic and PVC		"	
Aluminum		"	
Wood		"	
Vitrified tile		"	

FILTRATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repairs and overhauls manual and automatic control valves:			
Troubleshoots and diagnoses malfunction in manual and controlled valves		See Chem Add	
Installs, removes, and replaces valves		"	
Assembles and disassembles valves and control mechanisms		"	
Inspects and measures valve clearances		"	
Grinds, polishes, laps-in valves and valve seats		"	
Cleans and inspects valve actuating mechanisms		"	
Adjusts backlash in valve actuating mechanisms		"	
Lubricates valve actuating mechanisms		"	
Tests bellows and diaphragm actuators for leaks		"	
Calibrates valve position and control actuator		"	
Adjusts and replaces packing and seals		"	
Tests valves for complete opening and shut-off		"	
Tests functioning of control actuators (pneumatic, hydraulic, electrical, mechanical)		"	
Replaces worn or defective valve and actuator parts		"	
Repairs and overhauls storage tanks, drums, and vessels:			
Repairs leaks and defective portions of steel storage facilities		"	
Repairs leaks and defective portions of lined steel storage facilities		"	
Repairs leaks and defective portions of wood storage facilities		"	

FILTRATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repairs leaks and defective portions of concrete storage facilities	See Chem Add		
Diagnoses cause of rust, corrosion, and leaks	"		

REVERSE OSMOSIS	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Operations			
Monitors and verifies proper operation and condition of the following units of equipment:			
Reverse osmosis unit (plate-and-frame, large tube, spiral-wound module)	OP	2	1/Shift
Centrifugal and reciprocating pumps	"	2	"
Pressure measuring devices and control instrumentation	"	2	"
Flow measuring devices and control instrumentation	"	2	"
Steel pipe and pipe fittings	"	1	"
Belt, chain, and gear drive mechanisms	"	2	"
Electric motors, relays, and circuit breakers/ switches	"	2	"
pH status instrumentation	"	2	"
Conductivity status instrumentation	"	2	"
Reads and interprets status and control instrumentation:			
pH recorders and meters	"	2	"
Conductivity recorders and meters	"	2	"
Flow and pressure recorders and meters	"	2	"
Pilot lamps and alarms	"	2	"
Activates and controls units of equipment:			
Activates and controls high-pressure pumps	"	2	As Req
Adjusts manual valves to control pressure and flow rate	"	2	"
Overrides automatic controls to shutdown or correct in specific situations	"	3	"

REVERSE OSMOSIS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Activates and controls valves to bleed off concentrates	OP	2	1/Shift
Collects composite or grab samples for laboratory analysis	"	2	"
Preventive Maintenance Activities			
Services reverse osmosis units:			
Inspects RO units for leaks	"	2	"
Checks for rust and corrosion	"	2	wkly
Cleans and paints exterior	"	1	2/yr
Checks and adjusts tension on plate and frame components	"	2	dly
Services status and control instrumentation:			
Cleans and lubricates chart drive mechanisms	"	2	2/yr
Cleans electrical senors	"	2	mthly
Checks electrical contacts, connections, and wiring	"	2	wkly
Checks pneumatic sensors for leaks	"	2	"
Checks zero or null setting on galvanometers and pen recorders	"	2	"
Checks mechanical linkage for corrosion, rust, and freedom of movement	"	2	"
Cleans indicator covers and glass viewing windows	"	2	mthly
Cleans recorder pens and checks for ink flow	"	2	dly
Checks indicated values against known standards (checks calibration)	"	3	mthly

REVERSE OSMOSIS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Services electric motors and auxiliary equipment:			
Inspects motors for signs of overheating	OP	2	dly
Checks for excessive vibration or hum	"	2	dly
Checks wiring insulation	"	2	wkly
Checks for dirt or moisture	"	2	dly
Checks drive coupling and motor mounts for play/ loose fittings	"	2	dly
Checks for sticking brushes or excessive arcing	"	2	dly
Checks pilot lights and alarms	"	2	1/Shift
Checks points and contacts for pitting	"	2	mthly
Cleans and tightens electrical connections	"	2	mthly
Checks and lubricates bearings	"	1	wkly
Checks switches and circuit breakers for proper functioning	"	2	dly
Services centrifugal, reciprocating, and diaphragm pumps:			
Checks solenoid oiler flow; adjusts as necessary	"	2	wkly
Checks oil level in ball bearing housing; fills as necessary	"	1	dly
Checks grease cup; maintains proper pressure	"	2	dly
Checks enclosed shaft bearings; refills oil cup as necessary	"	2	dly
Checks ball-thrust bearings; adds fresh grease as necessary	"	2	mthly
Checks guide bearings; adds grease as necessary	"	2	"
Drains and adds fresh lubricant to shaft bearings	"	2	"
Flushes bearing housing and adds fresh grease	"	2	4/yr
Checks bearing temperatures; adjusts as necessary	"	2	wkly

REVERSE OSMOSIS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks stuffing boxes for leaks; tightens or repacks as necessary	OP	2	dly
Checks water-seal systems for leaks; adjusts pressure as necessary	"	2	dly
Clean and paint pump casing	"	1	dly
Check, clean, lubricate, and adjust float switch system	"	2	wkly
Inspect check valves for leaks	"	2	dly
Clean sediment and accumulated solids from sumps	"	1	mthly
Check and clean strainers	"	1	dly
Services flow measuring devices:			
Cleans and flushes annular chambers		See Chem Add	
Cleans and flushes piezometer pressure taps		"	
Cleans and dresses orifice plates		"	
Cleans and paints exterior		"	
Inspects interior for corrosion		"	
Purges connecting lines and fittings		"	
Services pipes and pipe fittings:			
Checks for leaks in pipes and pipe fittings		"	
Inspects for rust and corrosion		"	
Cleans and paints pipes and fittings		"	
Flushes dead-ends		"	
Checks and cleans sediment traps		"	
Checks and cleans wells and sumps		"	
Mechanically cleans pipes with augers and snakes		"	
Services manual and automatic control valves:			
Checks valves for leaks		"	
Inspects for rust and corrosion		"	

REVERSE OSMOSIS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks actuating bellows for leaks		See Chem Add	
Checks linkages for free movement		"	
Checks for complete opening and closing		"	
Checks calibration		"	
Lubricates control linkage		"	
Adjusts packing		"	
Cleans and paints exterior		"	
Cleans solenoid actuating mechanisms		"	
Services storage tanks, drums, and vessels:			
Checks for leaks		"	
Inspects for rust and corrosion		"	
Cleans and paints interior and exterior		"	
Removes accumulated deposits of sludge and sediment		"	
Services mechanical drive systems:			
Checks tension of flat and V-belt drives		"	
Checks and adjusts belt alignment		"	
Checks belts for wear		"	
Checks and adjusts chain drive slack		"	
Lubricates chain drive systems		"	
Checks lubricant levels in right-angle gear drives		"	
Checks lubricant levels in reduction gear boxes		"	
Drains and changes oil in sump systems		"	

REVERSE OSMOSIS (cont.)

Corrective Maintenance Activities

	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repairs and overhauls reverse osmosis units:			
Troubleshoots and diagnoses malfunctions in reverse osmosis units		Factory Rep	
Disassembles and assembles reverse osmosis units		"	
Inspects membranes for plugging and other defects		"	
Inspects gaskets and seals for defects and serviceability		"	
Cleans membranes and backing plates or supports		"	
Replaces membranes and seals		"	
Tests rebuilt units for high-pressure leaks and efficiency of operation		"	
Repairs and overhauls status and control instrumentation:			
Troubleshoots and diagnoses malfunctions in status and control instrumentation		See Chem Add	
Installs, removes, replaces status and control instrumentation		"	
Disassembles and reassembles status and control instrumentation		"	
Tests diaphragms, bourdon tubes, and bellows for leaks or defects		"	
Tests bimetallic strips and thermocouples for defects		"	
Tests electrical circuitry for shorts, open circuits, and resistance		"	

REVERSE OSMOSIS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Cleans and adds mercury to manometers		See Chem Add	
Cleans and sets contact points		"	
Cleans and checks knife edges		"	
Cleans and lubricates jeweled bearings		"	
Blows down pressure lines to remove restrictions or stoppages		"	
Cleans and checks orifices and nozzles		"	
Adjusts backlash in mechanical linkages		"	
Calibrates indicators and recorder pens against known standard		"	
Replaces worn or defective parts, seals, and bearings		"	
Repairs and overhauls electric motors and auxiliary equipment:			
Diagnoses and troubleshoots electrical malfunctions		"	
Installs, removes, replaces electric motors, wiring, and control devices		"	
Inspects and tests rotor and stator windings for shorts or open circuits		"	
Inspects commutator for wear, shorts, and signs of excessive heat		"	
Checks brushes for wear and proper spring tension		"	
Adjusts brushes to seat properly and prevent sticking		"	
Cleans, adjusts, and lubricates bearings		"	
Checks thermal switches, circuit breakers, and fuses		"	
Cleans and polishes collector rings		"	

REVERSE OSMOSIS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks and tightens pigtails and mechanical wire connections		See Chem Add	
Replaces or repairs defective parts in motors and control devices		"	
Adjusts rotor and shaft alignment		"	
Reconditions or replaces contacts on relays and switches		"	
Replaces defective wiring and conduit		"	
Inspects exposed equipment for defective gaskets and seals		"	
Measures voltage, current, and power consumption		"	
Checks motor speeds		"	
Repairs and overhauls centrifugal, reciprocating, and diaphragm pumps:			
Troubleshoots and diagnoses malfunctions in pumps		"	
Installs removes and replaces pumps		"	
Disassembles and assembles pumps		"	
Inspects and measures bearings and bearing races for defects		"	
Repacks ball-thrust bearings, roller bearings, and guide bearings		"	
Cleans and inspects pump interior		"	
Checks stuffing box for free movement of gland and excessive leakage		"	
Repacks gland assembly and adjusts		"	
Grinds and laps valves and valve seats		"	
Inspects impellers for deposits, scaling, and cavitation pits		"	

REVERSE OSMOSIS (cont.)

	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Dynamically balances impellers		See Chem Add	
Checks and aligns drive system		"	
Fits replacement parts		"	
Repairs bent float rods, binding mechanical fittings		"	
Lubricates mechanical fittings		"	
Cleans and paints exterior housing		"	
Repairs and replaces pipes and pipe fittings:			
Troubleshoots and diagnoses nature and location of stoppages		"	
Removes and replaces sections of pipe, pipe fittings, and couplings		"	
Cuts and threads pipe		"	
Cleans pipe using mechanical and hydraulically propelled tools		"	
Replaces gaskets and seals on flange type joints		"	
Bends pipe and tubing		"	
Tests pipe systems for pressure capability and leaks		"	
May be required to repair and replace special purpose pipe and fittings of the following types:			
Glass		"	
Glass or plastic lined steel		"	
Plastic and PVC		"	
Aluminum		"	
Wood		"	
Vitrified tile		"	

REVERSE OSMOSIS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repairs and overhauls manual and automatic control valves:			
Troubleshoots and diagnoses malfunction in manual and controlled valves		See Chem Add	
Installs, removes, and replaces valves		"	
Assembles and disassembles valves and control mechanisms		"	
Inspects and measures valve clearances		"	
Grinds, polishes, laps-in valves and valve seats		"	
Cleans and inspects valve actuating mechanisms		"	
Adjusts backlash in valve actuating mechanisms		"	
Lubricates valve actuating mechanisms		"	
Tests bellows and diaphragm actuators for leaks		"	
Calibrates valve position and control actuator		"	
Adjusts and replaces packing and seals		"	
Tests valves for complete opening and shut-off		"	
Tests functioning of control actuators (pneumatic, hydraulic, electrical, mechanical)		"	
Replaces worn or defective valve and actuator parts		"	
Repairs and overhauls storage tanks, drums, and vessels:			
Repairs leaks and defective portions of steel storage facilities		"	
Repairs leaks and defective portions of lined steel storage facilities		"	
Repairs leaks and defective portions of wood storage facilities		"	

REVERSE OSMOSIS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repairs leaks and defective portions of concrete storage facilities			
Diagnoses cause of rust, corrosion, and leaks	See Chem Add		
		"	

ELECTRODIALYSIS	OCCUPATIONAL AREA	SXILL LEVEL	FREQUENCY f
Operations			
Monitors and verifies proper operation and condition of the following units of equipment:			
Permeable membrane electrodialysis unit	OP	2	1/Shift
Centrifugal, reciprocating, and diaphragm pumps	"	2	"
Flow measuring devices and control instrumentation	"	2	"
Manual and automatic control valves	"	2	"
Steel, lined steel, and wood tanks and drums	"	1	"
Electric motors, relays, and circuit breakers/ switches	"	2	"
pH status instrumentation	"	2	"
Conductivity status instrumentation	"	2	"
Pressure status and control instrumentation	"	2	"
DC generator or rectifier	"	2	"
Reads and interprets status and control instrumentation:			
pH meters and recorders	"	2	"
ORP meters and recorders	"	2	"
Rate of flow meters and recorders	"	2	"
Pilot lamps and alarms	"	2	"
AC and DC voltmeters, ammeters, and wattmeters	"	2	"
Pressure indicators and recorders	"	2	"
Activates and controls units of equipment:			
Activates pumps and switches pumps in standby or parallel operations	"	2	As Req

ELECTRODIALYSIS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Adjusts manual valves to control pressure and flow rates	OP	2	As Req
Overrides automatic controls to shutdown or correct in specific situations	"	3	"
Adjusts and controls AC input to rectifiers or DC generators	"	2	"
Collects composite or grab samples for laboratory analysis	"	2	1/Shift
Preventive Maintenance Activities			
Services permeable membrane electrodialysis units:			
Checks pressure drop across input filter	"	2	"
Cleans or replaces input filter	"	2	"
Probes membrane stack with voltmeter to identify scale deposits	"	2	"
Checks membrane stack for leaks in anode, cathode, and dilute compartments	"	2	"
Inspects for rust and corrosion	"	2	wkly
Cleans and paints exterior	"	1	2/yr
Services status and control instrumentation:			
Cleans and lubricates chart drive mechanisms		See Chem Add	
Cleans electrical sensors		"	
Checks electrical contacts, connections, and wiring		"	
Checks pneumatic sensors for leaks		"	
Checks zero or null setting on galvanometers and pen recorders		"	

ELECTRODIALYSIS (cont.)

	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks mechanical linkage for corrosion, rust, and freedom of movement	See	Chem Add	
Cleans indicator covers and glass viewing windows		"	
Cleans recorder pens and checks for ink flow		"	
Checks indicated values against known standards (checks calibration)		"	
Services electric motors and auxiliary equipment:			
Inspects motors for signs of overheating		"	
Checks for excessive vibration or hum		"	
Checks wiring insulation		"	
Checks for dirt or moisture		"	
Checks drive coupling and motor mounts for play/loose fittings		"	
Checks for sticking brushes or excessive arcing		"	
Checks pilot lights and alarms		"	
Checks points and contacts for pitting		"	
Cleans and tightens electrical connections		"	
Checks and lubricates bearings		"	
Checks switches and circuit breakers for proper functioning		"	
Services centrifugal, reciprocating, and diaphragm pumps:			
Checks solenoid oiler flow; adjusts as necessary		"	
Checks oil level in ball bearing housing; fills as necessary		"	
Checks grease cup; maintains proper pressure		"	
Checks enclosed shaft bearings; refills oil cup as necessary		"	

ELECTRODIALYSIS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks ball-thrust bearings; adds fresh grease as necessary		See Chem Add	
Checks guide bearings; adds grease as necessary		"	
Drains and adds fresh lubricant to shaft bearings		"	
Flushes bearing housing and adds fresh grease		"	
Checks bearing temperatures; adjusts as necessary		"	
Checks stuffing boxes for leaks; tightens or repacks as necessary		"	
Checks water-seal systems for leaks; adjusts pressure as necessary		"	
Clean and paint pump casing		"	
Check, clean, lubricate, and adjust float switch system		"	
Inspect check valves for leaks		"	
Clean sediment and accumulated solids from sumps		"	
Check and clean strainers		"	
Services flow measuring devices:			
Cleans and flushes annular chambers		"	
Cleans and flushes piezometer pressure taps		"	
Cleans and dresses orifice plates		"	
Cleans and paints exterior		"	
Inspects interior for corrosion		"	
Purges connecting lines and fittings		"	
Services pipes and pipe fittings:			
Checks for leaks in pipes and pipe fittings		"	

ELECTRODIALYSIS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
		See Chem Add	
Inspects for rust and corrosion		"	
Cleans and paints pipes and fittings		"	
Flushes dead-ends		"	
Checks and cleans sediment traps		"	
Checks and cleans wells and sumps			
Mechanically cleans pipes with augers and snakes		"	
Services manual and automatic control valves:		"	
Checks valves for leaks		"	
Inspects for rust and corrosion		"	
Checks actuating bellows for leaks		"	
Checks linkages for free movement		"	
Checks for complete opening and closing		"	
Checks calibration		"	
Lubricates control linkage		"	
Adjusts packing		"	
Cleans and paints exterior		"	
Cleans solenoid actuating mechanisms			
Services storage tanks, drums, and vessels:		"	
Checks for leaks		"	
Inspects for rust and corrosion		"	
Cleans and paints interior and exterior			
Removes accumulated deposits of sludge and sediment		"	
Services mechanical drive systems:		"	
Checks tension of flat and V-belt drives		"	
Checks and adjusts belt alignment		"	
Checks belts for wear			

ELECTRODIALYSIS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks and adjusts chain drive slack		See Chem Add	
Lubricates chain drive systems		"	
Checks lubricant levels in right-angle gear drives		"	
Checks lubricant levels in reduction gear boxes		"	
Drains and changes oil in sump systems		"	
Corrective Maintenance Activities			
Repairs and overhauls permeable membrane electrodialysis units:			
Troubleshoots and diagnoses malfunctions in electrodialysis units		Factory Rep	
Assembles and disassembles electrodialysis units		"	
Cleans and inspects metal cathodes and anodes		"	
Cleans and inspects plastic cation membranes		"	
Cleans and inspects plastic anion membranes		"	
Cleans and inspects plastic spacers, seals, and gaskets		"	
Replaces unserviceable parts and membranes		"	
Tests efficiency of repaired or overhauled unit		"	
Repairs and overhauls status and control instrumentation:			
Troubleshoots and diagnoses malfunctions in status and control instrumentation		See Chem Add	

ELECTRODIALYSIS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Installs, removes, replaces status and control instrumentation		See Chem Add	
Disassembles and reassembles status and control instrumentation		"	
Tests diaphragms, bourdon tubes, and bellows for leaks or defects		"	
Tests bimetallic strips and thermocouples for defects		"	
Tests electrical circuitry for shorts, open circuits, and resistance		"	
Cleans and adds mercury to manometers		"	
Cleans and sets contact points		"	
Cleans and checks knife edges		"	
Cleans and lubricates jeweled bearings		"	
Blows down pressure lines to remove restrictions or stoppages		"	
Cleans and checks orifices and nozzles		"	
Adjusts backlash in mechanical linkages		"	
Calibrates indicators and recorder pens against known standard		"	
Replaces worn or defective parts, seals, and bearings		"	
Repairs and overhauls electric motors and auxiliary equipment:			
Diagnoses and troubleshoots electrical malfunctions		"	
Installs, removes, replaces electric motors, wiring, and control devices		"	
Inspects and tests rotor and stator windings for shorts or open circuits		"	

ELECTRODIALYSIS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Inspects commutator for wear, shorts, and signs of excessive heat		See Chem Add	
Checks brushes for wear and proper spring tension		"	
Adjusts brushes to seat properly and prevent sticking		"	
Cleans, adjusts, and lubricates bearings		"	
Checks thermal switches, circuit breakers, and fuses		"	
Cleans and polishes collector rings		"	
Checks and tightens pigtails and mechanical wire connections		"	
Replaces or repairs defective parts in motors and control devices		"	
Adjusts rotor and shaft alignment		"	
Reconditions or replaces contacts on relays and switches		"	
Replaces defective wiring and conduit		"	
Inspects exposed equipment for defective gaskets and seals		"	
Measures voltage, current, and power consumption		"	
Checks motor speeds		"	
Repairs and overhauls centrifugal, reciprocating, and diaphragm pumps:			
Troubleshoots and diagnoses malfunctions in pumps		"	
Installs, removes, and replaces pumps		"	
Disassembles and assembles pumps		"	

ELECTRODIALYSIS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Inspects and measures bearings and bearing races for defects		See Chem Add	
Repacks ball-thrust bearings, roller bearings, and guide bearings		"	
Cleans and inspects pump interior		"	
Checks stuffing box for free movement of gland and excessive leakage		"	
Repacks gland assembly and adjusts		"	
Grinds and laps valves and valve seats		"	
Inspects impellers for deposits, scaling, and cavitation pits		"	
Dynamically balances impellers		"	
Checks and aligns drive system		"	
Fits replacement parts		"	
Repairs bent float rods, binding mechanical fittings		"	
Lubricates mechanical fittings		"	
Cleans and paints exterior housing		"	
Repairs and replaces pipes and pipe fittings:			
Troubleshoots and diagnoses nature and location of stoppages		"	
Removes and replaces sections of pipe, pipe fittings, and couplings		"	
Cuts and threads pipe		"	
Cleans pipe using mechanical and hydraulically propelled tools		"	
Replaces gaskets and seals on flange type joints		"	
Bends pipe and tubing		"	

ELECTRODIALYSIS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Tests pipe systems for pressure capability and leaks		See Chem Add	
May be required to repair and replace special purpose pipe and fittings of the following types:			
Glass		"	
Glass or plastic lined steel		"	
Plastic and PVC		"	
Aluminum		"	
Wood		"	
Vitrified tile		"	
Repairs and overhauls manual and automatic control valves:			
Troubleshoots and diagnoses malfunction in manual and controlled valves		"	
Installs, removes, and replaces valves		"	
Assembles and disassembles valves and control mechanisms		"	
Inspects and measures valve clearances		"	
Grinds, polishes, laps-in valves and valve seats		"	
Cleans and inspects valve actuating mechanisms		"	
Adjusts backlash in valve actuating mechanisms		"	
Lubricates valve actuating mechanisms		"	
Tests bellows and diaphragm actuators for leaks		"	
Calibrates valve position and control actuator		"	
Adjusts and replaces packing and seals		"	

ELECTRODIALYSIS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Tests valves for complete opening and shut-off		See Chem Add	
Tests functioning of control actuators (pneumatic, hydraulic, electrical, mechanical)		"	
Replaces worn or defective valve and actuator parts		"	
Repairs and overhauls storage tanks, drums, and vessels:			
Repairs leaks and defective portions of steel storage facilities		"	
Repairs leaks and defective portions of lined steel storage facilities		"	
Repairs leaks and defective portions of wood storage facilities		"	
Repairs leaks and defective portions of concrete storage facilities		"	
Diagnoses cause of rust, corrosion, and leaks		"	
Repairs and overhauls mechanical appurtenances:			
Troubleshoots and diagnoses malfunctions in mechanical systems		"	
Disassembles and assembles mechanical drive systems		"	
Inspects and measures gear drives for wear and defects		"	
Inspects chain drives, replaces defective links, adjusts tension		"	
Checks and measures sprocket alignment		"	
Inspects sprocket teeth for wear, hooks, and other defects		"	

ELECTRODIALYSIS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Inspects and measures bearings and races for wear and defects		See Chem Add	
Cleans and finishes moving parts to prevent freezing or binding		"	
Repacks bearings		"	
Fits and replaces parts showing excessive wear or defects		"	
Inspects and replaces water and oil seals as necessary		"	
Cleans and paints exposed surfaces		"	
Replaces drive belts, pulleys, and tensioning devices		"	

Note: The electrodialysis unit and DC power supplies used in this treatment pose electrical hazards.

ION EXCHANGE	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Operations			
Monitors and verifies the proper operation and condition of the following units of equipment:			
Sodium cation exchange units	OP	2	1/Shift
Hydrogen cation exchange units	"	2	"
Anion exchanger units	"	2	"
Centrifugal, reciprocating, and diaphragm pumps	"	2	"
Pressure measuring and control devices	"	2	"
Flow measuring devices and control instrumentation	"	2	"
Steel pipe and pipe fittings	"	1	"
Belt, chain, and gear drive mechanisms	"	2	"
Electric motors, relays, and circuit breakers/switches	"	2	"
pH status instrumentation	"	2	"
Conductivity status instrumentation	"	2	"
Dry and liquid chemical feeders and injectors	"	2	"
Reads and interprets status and control instrumentation:			
pH recorders and meters	"	2	"
Rate of flow meters and recorders	"	2	"
Pressure recorders and meters	"	2	"
Pilot lamps and alarms	"	2	"
Conductivity meters and recorders	"	2	"
Activates and controls units of equipment:			
Adjusts and controls manual valves to accomplish regeneration	"	2	"

ION EXCHANGE (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Overrides automatic controls to correct in specific situations	OP	3	1/Shift
Adjusts regeneration cycle time and wash flow rate	"	3	As Req
Activates and controls influent and chemical feed pumps	"	2	"
Collects composite or grab samples for laboratory analysis	"	2	1/Shift
Collects and disposes of backwash from regeneration	"	2	"
Maintains supply of regeneration chemicals in tanks and hoppers	"	1	"
Preventive Maintenance Activities			
Services ion exchange units:			
Inspects gravity and pressure flow ion exchange units for leaks	"	2	"
Checks for rust and corrosion	"	2	"
Cleans and paints exterior	"	1	2/yr
Services dry chemical feeders:			
Removes chemical dust accumulations from hoppers and feed mechanism		See Chem Add	
Checks for loose bolts and defective parts		"	
Cleans solution tanks of accumulated sediment		"	
Lubricates drive mechanism and moving parts		"	

ION EXCHANGE (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks for rust/corrosion		See Chem Add	
Checks rate of feed against known standard		"	
Paints exposed parts		"	
Services liquid displacement feeders:			
Cleans sediment from trap and chemical storage tanks		"	
Checks for loose or defective parts		"	
Lubricates moving parts and drive mechanisms		"	
Checks pilot tubes and needle valves for proper operation		"	
Checks rate of feed against known standard		"	
Paints exposed parts		"	
Services status and control instrumentation:			
Cleans and lubricates chart drive mechanisms		"	
Cleans electrical sensors		"	
Checks electrical contacts, connections, and wiring		"	
Checks pneumatic sensors for leaks		"	
Checks zero or null setting on galvanometers and pen recorders		"	
Checks mechanical linkage for corrosion, rust, and freedom of movement		"	
Cleans indicator covers and glass viewing windows		"	
Cleans recorder pens and checks for ink flow		"	
Checks indicated values against known standards (checks calibration)		"	

ION EXCHANGE (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Services electric motors and auxiliary equipment:			
Inspects motors for signs of overheating		See Chem Add	
Checks for excessive vibration or hum		"	
Checks wiring insulation		"	
Checks for dirt or moisture		"	
Checks drive coupling and motor mounts for play/loose fittings		"	
Checks for sticking brushes or excessive arcing		"	
Checks pilot lights and alarms		"	
Checks points and contacts for pittings		"	
Cleans and tightens electrical connections		"	
Checks and lubricates bearings		"	
Checks switches and circuit breakers for proper functioning		"	
Services centrifugal, reciprocating, and diaphragm pumps:			
Checks solenoid oiler flow; adjusts as necessary		"	
Checks oil level in ball bearing housing; fills as necessary		"	
Checks grease cup; maintains proper pressure		"	
Checks enclosed shaft bearings; refills oil cup as necessary		"	
Checks ball-thrust bearings; adds fresh grease as necessary		"	
Checks guide bearings; adds grease as necessary		"	
Drains and adds fresh lubricant to shaft bearings		"	
Flushes bearing housing and adds fresh grease		"	

ION EXCHANGE (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks bearing temperatures; adjusts as necessary		See Chem Add	
Checks stuffing boxes for leaks; tightens or repacks as necessary		"	
Checks water-seal systems for leaks; adjusts pressure as necessary		"	
Clean and paint pump casing		"	
Check, clean, lubricate, and adjust float switch system		"	
Inspect check valves for leaks		"	
Clean sediment and accumulated solids from sumps		"	
Check and clean strainers		"	
Services flow measuring devices:			
Cleans and flushes annular chambers		"	
Cleans and flushes piezometer pressure taps		"	
Cleans and dresses orifice plates		"	
Cleans and paints exterior		"	
Inspects interior for corrosion		"	
Purges connecting lines and fittings		"	
Services pipes and pipe fittings:			
Checks for leaks in pipes and pipe fittings		"	
Inspects for rust and corrosion		"	
Cleans and paints pipes and fittings		"	
Flushes dead-ends		"	
Checks and cleans sediment traps		"	
Checks and cleans wells and sumps		"	
Mechanically cleans pipes with augers and snakes		"	

ION EXCHANGE (cont.)

	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Services manual and automatic control valves:		See Chem Add	
Checks valves for leaks		"	
Inspects for rust and corrosion		"	
Checks actuating bellows for leaks		"	
Checks linkages for free movement		"	
Checks for complete opening and closing		"	
Checks calibration		"	
Lubricates control linkage		"	
Adjusts packing		"	
Cleans and paints exterior		"	
Cleans solenoid actuating mechanisms			
Services storage tanks, drums, and vessels:		"	
Checks for leaks		"	
Inspects for rust and corrosion		"	
Cleans and paints interior and exterior			
Removes accumulated deposits of sludge and sediment		"	
Services mechanical drive systems:		"	
Checks tension of flat and V-belt drives		"	
Checks and adjusts belt alignment		"	
Checks belts for wear		"	
Checks and adjusts chain drive slack		"	
Lubricates chain drive systems			
Checks lubricant levels in right-angle gear drives		"	
Checks lubricant levels in reduction gear boxes		"	
Drains and changes oil in sump systems		"	

ION EXCHANGE (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Cleans and inspects variable speed belt drive systems		See Chem Add	
Lubricates thrust and frame bearings for drive shafts		"	
Checks oil seals for leaks		"	
Lubricates pressure grease fittings		"	
Corrective Maintenance Activities			
Repairs and overhauls ion exchange units:			
Troubleshoots and diagnoses malfunctions in ion exchange units		Factory Rep	
Disassembles and assembles ion exchange units		"	
Cleans and inspects water distributor for clogging or defects		"	
Repairs or replaces resin bed supports		"	
Inspects gaskets and seals for defects and serviceability		"	
Replaces defective parts and seals		"	
Repairs and overhauls dry chemical feeders:			
Troubleshoots and diagnoses malfunctions		See Chem Add	
Installs, removes, and replaces chemical feeder units		"	
Inspects and measures parts for wear and defects		"	
Checks and adjusts stroke rods		"	
Cleans pockets of star feeder and scraper		"	
Checks and cleans feeding gates		"	
Checks feeder scale sensitivity and null balance		"	

ION EXCHANGE (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Replaces worn or defective parts and bearings		See Chem Add	
Fits parts, seals, and gaskets		"	
Reassembles feeding unit		"	
Tests and calibrates feed rate against known standard		"	
Cleans and paints all exposed surfaces		"	
Repairs and overhauls liquid and solution chemical feeders:			
Troubleshoots and diagnoses malfunctions		"	
Installs, removes, and replaces chemical feeder units		"	
Disassembles feeder units and reassembles		"	
Inspects and measures parts for wear and defects		"	
Repairs linings and diaphragms		"	
Measures and adjusts float valve settings		"	
Fits parts, seals, and gaskets		"	
Replaces worn or defective parts, seals, and gaskets		"	
Tests and calibrates feed rate against known standard		"	
Cleans and paints all exposed surfaces		"	
Repairs and overhauls status and control instrumentation:			
Troubleshoots and diagnoses malfunctions in status and control instrumentation		"	
Installs, removes, replaces status and control instrumentation		"	

ION EXCHANGE (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Disassembles and reassembles status and control instrumentation		See Chem Add	
Tests diaphragms, bourdon tubes, and bellows for leaks or defects		"	
Tests bimetallic strips and thermocouples for defects		"	
Tests electrical circuitry for shorts, open circuits, and resistance		"	
Cleans and adds mercury to manometers		"	
Cleans and sets contact points		"	
Cleans and checks knife edges		"	
Cleans and lubricates jeweled bearings		"	
Blows down pressure lines to remove restrictions or stoppages		"	
Cleans and checks orifices and nozzles		"	
Adjusts backlash in mechanical linkages		"	
Calibrates indicators and recorder pens against known standard		"	
Replaces worn or defective parts, seals, and bearings		"	
Repairs and overhauls electric motors and auxiliary equipment:			
Diagnoses and troubleshoots electrical malfunctions		"	
Installs, removes, replaces electric motors, wiring, and control devices		"	
Inspects and tests rotor and stator windings for shorts or open circuits		"	
Inspects commutator for wear, shorts, and signs of excessive heat		"	

ION EXCHANGE (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks brushes for wear and proper spring tension		See Chem Add	
Adjusts brushes to seat properly and prevent sticking		"	
Cleans, adjusts, and lubricates bearings		"	
Checks thermal switches, circuit breakers, and fuses		"	
Cleans and polishes collector rings		"	
Checks and tightens pigtails and mechanical wire connections		"	
Replaces or repairs defective parts in motors and control devices		"	
Adjusts rotor and shaft alignment		"	
Reconditions or replaces contacts on relays and switches		"	
Replaces defective wiring and conduit		"	
Inspects exposed equipment for defective gaskets and seals		"	
Measures voltage, current, and power consumption		"	
Checks motor speeds		"	
Repairs and overhauls centrifugal, reciprocating, and diaphragm pumps:			
Troublesshoots and diagnoses malfunctions in pumps		"	
Installs, removes, and replaces pumps		"	
Disassembles and assembles pumps		"	
Inspects and measures bearings and bearing races for defects		"	

ION EXCHANGE (cont.)

	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repacks ball-thrust bearings, roller bearings, and guide bearings		See Chem Add	
Cleans and inspects pump interior		"	
Checks stuffing box for free movement of gland and excessive leakage		"	
Repacks gland assembly and adjusts		"	
Grinds and laps valves and valve seats		"	
Inspects impellers for deposits, scaling, and cavitation pits		"	
Dynamically balances impellers		"	
Checks and aligns drive system		"	
Fits replacement parts		"	
Repairs bent float rods, binding mechanical fittings		"	
Lubricates mechanical fittings		"	
Cleans and paints exterior housing		"	
Repairs and replaces pipes and pipe fittings:			
Troubleshoots and diagnoses nature and location of stoppages		"	
Removes and replaces sections of pipe, pipe fittings, and couplings		"	
Cuts and threads pipe		"	
Cleans pipe using mechanical and hydraulically propelled tools		"	
Replaces gaskets and seals on flange type joints		"	
Bends pipe and tubing		"	
Tests pipe systems for pressure capability and leaks		"	

ION EXCHANGE (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
May be required to repair and replace special purpose pipe and fittings of the following types:			
Glass		See Chem Add	
Glass or plastic lined steel		"	
Plastic and PVC		"	
Aluminum		"	
Wood		"	
Vertrified tile		"	
Repairs and overhauls manual and automatic control valves:			
Troubleshoots and diagnoses malfunction in manual and controlled valves		"	
Installs, removes, and replaces valves		"	
Assembles and disassembles valves and control mechanisms		"	
Inspects and measures valve clearances		"	
Grinds, polishes, laps-in valves and valve seats		"	
Cleans and inspects valve actuating mechanisms		"	
Adjusts backlash in valve actuating mechanisms		"	
Lubricates valve actuating mechanisms		"	
Tests bellows and diaphragm actuators for leaks		"	
Calibrates valve position and control actuator		"	
Adjusts and replaces packing and seals		"	
Tests valves for complete opening and shut-off		"	
Tests functioning of control actuators (pneumatic, hydraulic, electrical, mechanical)		"	
Replaces worn or defective valve and actuator parts		"	

ION EXCHANGE (cont.)

	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repairs and overhauls storage tanks, drums, and vessels:			
Repairs leaks and defective portions of steel storage facilities		See Chem Add	
Repairs leaks and defective portions of lined steel storage facilities		"	
Repairs leaks and defective portions of wood storage facilities		"	
Repairs leaks and defective portions of concrete storage facilities		"	
Diagnoses cause of rust, corrosion, and leaks		"	

Note: Acids and alkalies used in this treatment are extremely hazardous.

MULTIPLE EFFECT EVAPORATORS	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Operations			
Monitors and verifies proper operation and condition of the following units of equipment:			
Single and multiple stage evaporators and condensers	OP	2	1/Shift
Steam, coal, gas, or oil heat exchange medium	"	2	"
Temperature status and control instrumentation	"	2	"
Electric motors, relays, and circuit breakers/ switches	"	2	"
Pressure status and control instrumentation	"	2	"
Centrifugal and reciprocating pumps	"	2	"
Iron, steel, and copper pipe and pipe fittings	"	1	"
Manual and automatic control valves	"	2	"
Steel and lined steel tanks, drums, and vessels	"	1	"
Belt, chain, and gear drive mechanisms	"	2	"
Flow recorders and meters/level indicators	"	2	"
Reads and interprets status and control instrumentation:			
Temperature gages and recorders	"	2	"
Pressure gages and recorders	"	2	"
Flow meters and recorders	"	2	"
Pilot lamps and voltage/current recorders and meters	"	2	"
Manometers and sight glasses	"	2	"

MULTIPLE EFFECT EVAPORATORS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Activates and controls units of equipment:			
Controls manual valves for feedwater inlet, blowdown, and distillate	OP	2	As Req
Overrides automatic control valves to correct in emergency situations	"	3	"
Adjusts steam or fuel feeds/forced draft blowers	"	2	"
Switches to standby or parallel pumps	"	2	"
Removes and disposes of blowdown	"	1	1/Shift
Collects composite or grab samples of blowdown and feedwater for laboratory analysis	"	2	"
Preventive Maintenance Activities			
Services multiple effect evaporators:			
Drains and cleans evaporator shell and tube nest with soda or acid solution to remove scale	"	2	4/yr
Cleans evaporator chamber using steam hose, brushes, and scrapers	"	2	"
Checks for rust and corrosion	"	2	wkly
Inspects for leaks	"	2	1/Shift
Services status and control instrumentation:			
Cleans and lubricates chart drive mechanisms	"	2	2/yr
Cleans electrical sensors	"	2	mthly
Checks electrical contacts, connections, and wiring	"	2	wkly

MULTIPLE EFFECT EVAPORATORS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks pneumatic sensors for leaks	OP	2	wkly
Checks zero or null setting on galvanometers and on pen recorders	"	2	"
Checks mechanical linkage for corrosion, rust, and freedom of movement	"	2	"
Cleans indicator covers and glass viewing windows	"	2	mthly
Cleans recorder pens and checks for ink flow	"	2	dly
Checks indicated values against known standards (checks calibration)	"	3	mthly
Services electric motors and auxiliary equipment:			
Inspects motors for signs of overheating	"	2	dly
Checks for excessive vibration or hum	"	2	dly
Checks wiring insulation	"	2	wkly
Checks for dirt or moisture	"	2	dly
Checks drive coupling and motor mounts for play/loose fittings	"	2	dly
Checks for sticking brushes or excessive arcing	"	2	dly
Checks pilot lights and alarms	"	2	1/Shift
Checks points and contacts for pitting	"	2	mthly
Cleans and tightens electrical connections	"	2	mthly
Checks and lubricates bearings	"	1	wkly
Checks switches and circuit breakers for proper functioning	"	2	dly
Services centrifugal, reciprocating, and diaphragm pumps:			
Checks solenoid oiler flow; adjusts as necessary	"	2	wkly
Checks oil level in ball bearing housing; fills as necessary	"	1	dly

MULTIPLE EFFECT EVAPORATORS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks grease cup; maintains proper pressure	OP	2	dly
Checks enclosed shaft bearings; refills oil cup as necessary	"	2	dly
Checks ball-thrust bearings; adds fresh grease as necessary	"	2	mthly
Checks guide bearings; adds grease as necessary	"	2	wkly
Drains and adds fresh lubricant to shaft bearings	"	2	mthly
Flushes bearing housing and adds fresh grease	"	2	4/yr
Checks bearing temperatures; adjusts as necessary	"	2	wkly
Checks stuffing boxes for leaks; tightens or repacks as necessary	"	2	dly
Checks water-seal systems for leaks; adjusts pressure as necessary	"	2	dly
Clean and paint pump casing	"	1	dly
Check, clean, lubricate, and adjust float switch system	"	2	wkly
Inspect check valves for leaks	"	2	dly
Clean sediment and accumulated solids from sumps	"	1	mthly
Check and clean strainers	"	1	dly
Services flow measuring devices:			
Cleans and flushes annular chambers	"	2	mthly
Cleans and flushes piezometer pressure taps	"	2	mthly
Cleans and dresses orifice plates	"	2	2/yr
Cleans and paints exterior	"	1	yrly
Inspects interior for corrosion	"	2	mthly
Purges connecting lines and fittings	"	2	wkly

MULTIPLE EFFECT EVAPORATORS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Services pipes and pipe fittings:			
Checks for leaks in pipes and pipe fittings	OP	1	wkly
Inspects for rust and corrosion	"	1	wkly
Cleans and paints pipes and fittings	"	1	yrly
Flushes dead-ends	"	2	mthly
Checks and cleans sediment traps	"	1	wkly
Checks and cleans wells and sumps	"	1	wkly
Mechanically cleans pipes with augers and snakes	"	2	As Req
Services manual and automatic control valves:			
Checks valves for leaks	"	2	dly
Inspects for rust and corrosion	"	2	wkly
Checks actuating bellows for leaks	"	2	dly
Checks linkages for free movement	"	2	dly
Checks for complete opening and closing	"	2	dly
Checks calibration	"	3	mthly
Lubricates control linkage	"	2	wkly
Adjusts packing	"	2	wkly
Cleans and paints exterior	"	1	yrly
Cleans solenoid actuating mechanisms	"	2	dly
Services storage tanks, drums, and vessels:			
Checks for leaks	"	1	dly
Inspects for rust and corrosion	"	1	wkly
Cleans and paints interior and exterior	"	1	yrly
Removes accumulated deposits of sludge and sediment	"	1	wkly

MULTIPLE EFFECT EVAPORATORS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Services mixing and blending equipment:			
Cleans deposits from paddles, arms, and propellers	OP	1	wkly
Inspects for rust and corrosion	"	1	"
Inspects mechanical drive functioning	"	2	"
Lubricates mechanical drive system	"	2	"
Paints and protects exposed surfaces	"	1	yrly
Checks for homogeneity of mixed substances	"	2	dly
Checks speed of mixing or blending	"	2	dly
Servicesmechanical drive systems:			
Checks tension of flat and V-belt drives	"	2	dly
Checks and adjusts belt alignment	"	2	dly
Checks belts for wear	"	2	wkly
Checks and adjusts chain drive slack	"	2	"
Lubricates chain drive systems	"	2	"
Checks lubricant levels in right-angle gear drives	"	2	"
Checks lubricant levels in reduction gear boxes	"	2	"
Drains and changes oil in sump systems	"	2	mthly
Cleans and inspects variable speed belt drive systems	"	2	wkly
Lubricates thrust and frame bearings for drive shafts	"	2	"
Checks oil seals for leaks	"	2	dly
Lubricates pressure grease fittings	"	2	wkly

MULTIPLE EFFECT EVAPORATORS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Corrective Maintenance Activities			
Repairs and overhauls multiple effect evaporators:			
Troubleshoots and diagnoses malfunctions	Evap Repmn	3	As Req
Installs, removes, and replaces double pipe or shell and tube exchangers	"	3	"
Repairs leaks in evaporators and condensers	"	3	"
Uses compressed air rotary scraper to remove heavy scale deposits from tubes	"	3	"
Fits parts, seals and gaskets	"	3	"
Repairs and overhauls status and control instrumentation:			
Troubleshoots and diagnoses malfunctions in status and control instrumentation	Ins Repmn	3	"
Installs, removes, replaces status and control instrumentation	"	3	"
Disassembles and reassembles status and control instrumentation	"	3	"
Tests disphragms, bourdon tubes, and bellows for leaks or defects	"	3	"
Tests bimetallic strips and thermocouples for defects	"	3	"
Tests electrical circuitry for shorts, open circuits, and resistance	"	3	"
Cleans and adds mercury to manometers	"	3	"
Cleans and sets contact points	"	3	"
Cleans and checks knife edges	"	3	"
Cleans and lubricates jeweled bearings	"	3	"
Blows down pressure lines to remove restrictions or stoppages	"	3	"

MULTIPLE EFFECT EVAPORATORS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Cleans and checks orifices and nozzles	Ins Repmn	3	As Req
Adjusts backlash in mechanical linkages	"	3	"
Calibrates indicators and recorder pens against known standard	"	3	"
Replaces worn or defective parts, seals, and bearings	"	3	"
Repairs and overhauls electric motors and auxiliary equipment:			
Diagnoses and troubleshoots electrical malfunctions	Elec	3	"
Installs, removes, replaces electric motors, wiring, and control devices	"	3	"
Inspects and tests rotor and stator windings for shorts or open circuits	"	3	"
Inspects commutator for wear, shorts, and signs of excessive heat	"	3	"
Checks brushes for wear and proper spring tension	"	3	"
Adjusts brushes to seat properly and prevent sticking	"	3	"
Cleans, adjusts, and lubricates bearings	"	3	"
Checks thermal switches, circuit breakers, and fuses	"	3	"
Cleans and polishes collector rings	"	3	"
Checks and tightens pigtails and mechanical wire connections	"	3	"
Replaces or repairs defective parts in motors and control devices	"	3	"
Adjusts rotor and shaft alignment	"	3	"

MULTIPLE EFFECT EVAPORATORS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Replaces defective wiring and conduit	Elec	3	As Req
Inspects exposed equipment for defective gaskets and seals	"	3	"
Measures voltage, current, and power consumption	"	3	"
Checks motor speeds	"	3	"
Repairs and overhauls centrifugal, reciprocating, and diaphragm pumps:			
Troubleshoots and diagnoses malfunctions in pumps	Pump Serv	3	"
Installs, removes, and replaces pumps	"	3	"
Disassembles and assembles pumps	"	3	"
Inspects and measures bearings and bearing races for defects	"	3	"
Repacks ball-thrust bearings, roller bearings, and guide bearings	"	3	"
Cleans and inspects pump interior	"	3	"
Checks stuffing box for free movement of gland and excessive leakage	"	3	"
Repacks gland assembly and adjusts	"	3	"
Grinds and laps valves and valve seats	"	3	"
Inspects impellers for deposits, scaling, and cavitation pits	"	3	"
Dynamically balances impellers	"	3	"
Checks and aligns drive system	"	3	"
Fits replacement parts	"	3	"
Repairs bent float rods, binding mechanical fittings	"	3	"
Lubricates mechanical fittings	"	3	"
Cleans and paints exterior housing	"	3	"

MULTIPLE EFFECT EVAPORATORS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repairs and replaces pipes and pipe fittings:			
Troubleshoots and diagnoses nature and location of stoppages	Pipe Ftr	3	As Req
Removes and replaces sections of pipe, pipe fittings, and couplings	"	3	"
Cuts and threads pipe	"	3	"
Cleans pipe using mechanical and hydraulically propelled tools	"	3	"
Replaces gaskets and seals on flange type joints	"	3	"
Bends pipe and tubing	"	3	"
Tests pipe systems for pressure capability and leaks	"	3	"
May be required to repair and replace special purpose pipe and fittings of the following types:			
Glass	"	3	"
Glass or plastic lined steel	"	3	"
Plastic and PVC	"	3	"
Aluminum	"	3	"
Wood	"	3	"
Vitrified tile	"	3	"
Repairs and overhauls manual and automatic control valves:			
Troubleshoots and diagnoses malfunction in manual and controlled valves	Ins Repmn	3	"
Installs, removes, and replaces valves	"	3	"
Assembles and disassembles valves and control mechanisms	"	3	"

MULTIPLE EFFECT EVAPORATORS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Inspects and measures valve clearances	Ins Repmn	3	As Req
Grinds, polishes, laps-in valves and valve seats	"	3	"
Cleans and inspects valve actuating mechanisms	"	3	"
Adjusts backlash in valve actuating mechanisms	"	3	"
Lubricates valve actuating mechanisms	"	3	"
Tests bellows and diaphragm actuators for leaks	"	3	"
Calibrates valve position and control actuator	"	3	"
Adjusts and replaces packing and seals	"	3	"
Tests valves for complete opening and shut-off	"	3	"
Tests functioning of control actuators (pneumatic, hydraulic, electrical, mechanical)	"	3	"
Replaces worn or defective valve and actuator parts	"	3	"
Repairs and overhauls storage tanks drums, and vessels:			
Repairs leaks and defective portions of steel storage facilities	Mech Main	3	"
Repairs leaks and defective portions of lined steel storage facilities	"	3	"
Repairs leaks and defective portions of wood storage facilities	"	3	"
Repairs leaks and defective portions of concrete storage facilities	"	3	"
Diagnoses cause of rust, corrosion, and leaks	"	3	"

DEEP WELL INJECTION	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Operations			
Monitors and verifies proper operation and condition of the following units of equipment:			
Centrifugal and reciprocating pumps	OP	2	1/Shift
Electric motors, relays, and circuit breakers/ switches	"	2	"
Pressure meters and recorders	"	2	"
Belt, chain, and gear drive mechanisms	"	2	"
Iron and steel pipe and pipe fittings	"	1	"
Flow measuring devices and recorders	"	2	"
Manual and automatic control valves	"	2	"
Temperature measuring devices and recorders	"	2	"
Reads and interprets status and control instrumentation:			
Temperature gauges and recorders	"	2	"
Flow rate instruments and controllers	"	2	"
Pressure instruments and controllers	"	2	"
Pilot lamps and alarms	"	2	"
Activates and controls units of equipment:			
Adjusts and controls injection rate	"	3	As Req
Switches to standby or parallel pumps	"	2	"
Overrides automatic controls to adjust in specific situations	"	3	"
Adjusts manual valves to achieve specified flow, pressure, or volume	"	2	"
Collects composite or grab samples for laboratory analysis	"	2	"

DEEP WELL INJECTION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Preventive Maintenance Activities			
Services status and control instrumentation:			
Cleans and lubricates chart drive mechanisms		See Chem Add	
Cleans electrical sensors		"	
Checks electrical contacts, connections, and wiring		"	
Checks pneumatic sensors for leaks		"	
Checks zero or null setting on galvanometers and pen recorders		"	
Checks mechanical linkage for corrosion, rust, and freedom of movement		"	
Cleans indicator covers and glass viewing windows		"	
Cleans recorder pens and checks for ink flow		"	
Checks indicated values against known standards (checks calibration)		"	
Services electric motors and auxiliary equipment:			
Inspects motors for signs of overheating		"	
Checks for excessive vibration or hum		"	
Checks wiring insulation		"	
Checks for dirt or moisture		"	
Checks drive coupling and motor mounts for play/loose fittings		"	
Checks for sticking brushes or excessive arcing		"	
Checks pilot lights and alarms		"	
Checks points and contacts for pitting		"	
Cleans and tightens electrical connections		"	
Checks and lubricates bearings		"	
Checks switches and circuit breakers for proper functioning		"	

DEEP WELL INJECTION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Services centrifugal and reciprocating pumps:			
Checks solenoid oiler flow; adjusts as necessary		See Chem Add	
Checks oil level in ball bearing housing; fills as necessary		"	
Checks grease cup; maintains proper pressure		"	
Checks enclosed shaft bearings; refills oil cup as necessary		"	
Checks ball-thrust bearings; adds fresh grease as necessary		"	
Checks guide bearings; adds grease as necessary		"	
Drains and adds fresh lubricant to shaft bearings		"	
Flushes bearing housing and adds fresh grease		"	
Checks bearing temperatures; adjusts as necessary		"	
Checks stuffing boxes for leaks; tightens or repacks as necessary		"	
Checks water-seal systems for leaks; adjusts pressure as necessary		"	
Clean and paint pump casing		"	
Check, clean, lubricate, and adjust float switch system		"	
Inspect check valves for leaks		"	
Clean sediment and accumulated solids from sumps		"	
Check and clean strainers		"	
Services flow measuring devices:			
Cleans and flushes annular chambers		"	
Cleans and flushes piezometer pressure taps		"	
Cleans and dresses orifice plates		"	
Cleans and paints exterior		"	

DEEP WELL INJECTION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Inspects interior for corrosion		See Chem Add	
Purges connecting lines and fittings		"	
Services pipes and pipe fittings:			
Checks for leaks in pipes and pipe fittings		"	
Inspects for rust and corrosion		"	
Cleans and paints pipes and fittings		"	
Flushes dead-ends		"	
Checks and cleans sediment traps		"	
Checks and cleans wells and sumps		"	
Mechanically cleans pipes with augers and snakes		"	
Services manual and automatic control valves:			
Checks valves for leaks		"	
Inspects for rust and corrosion		"	
Checks actuating bellows for leaks		"	
Checks linkages for free movement		"	
Checks for complete opening and closing		"	
Checks calibration		"	
Lubricates control linkage		"	
Adjusts packing		"	
Cleans and paints exterior		"	
Cleans solenoid actuating mechanisms		"	
Services storage tanks, drums, and vessels:			
Checks for leaks		"	
Inspects for rust and corrosion		"	
Cleans and paints interior and exterior		"	
Removes accumulated deposits of sludge and sediment		"	

DEEP WELL INJECTION (cont.)

	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Services mechanical drive systems:			
Checks tension of flat and V-belt drives		See Chem Add	
Checks and adjusts belt alignment		"	
Checks belts for wear		"	
Checks and adjusts chain drive slack		"	
Lubricates chain drive systems		"	
Checks lubricant levels in right-angle gear drives		"	
Checks lubricant levels in reduction gear boxes		"	
Drains and changes oil in sump systems		"	
Cleans and inspects variable speed belt drive systems		"	
Lubricates thrust and frame bearings for drive shafts		"	
Checks oil seals for leaks		"	
Lubricates pressure grease fittings		"	

Corrective Maintenance Activities

	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repairs and overhauls status and control instrumentation:			
Troubleshoots and diagnoses malfunctions in status and control instrumentation		"	
Installs, removes, replaces status and control instrumentation		"	
Disassembles and reassembles status and control instrumentation		"	
Tests diaphragms, bourdon tubes, and bellows for leaks or defects		"	

DEEP WELL INJECTION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Tests bimetallic strips and thermocouples for defects		See Chem Add	
Tests electrical circuitry for shorts, open circuits, and resistance		"	
Cleans and adds mercury to manometers		"	
Cleans and sets contact points		"	
Cleans and checks knife edges		"	
Cleans and lubricates jeweled bearings		"	
Blows down pressure lines to remove restrictions or stoppages		"	
Cleans and checks orifices and nozzles		"	
Adjusts backlash in mechanical linkages		"	
Calibrates indicators and recorder pens against known standard		"	
Replaces worn or defective parts, seals, and bearings		"	
Repairs and overhauls electric motors and auxiliary equipment:			
Diagnoses and troubleshoots electrical malfunctions		"	
Installs, removes, replaces electric motors, wiring, and control devices		"	
Inspects and tests rotor and stator windings for shorts or open circuits		"	
Inspects commutator for wear, shorts, and signs of excessive heat		"	
Checks brushes for wear and proper spring tension		"	
Adjusts brushes to seat properly and prevent sticking		"	

DEEP WELL INJECTION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Cleans, adjusts, and lubricates bearings		See Chem Add	
Checks thermal switches, circuit breakers, and fuses		"	
Cleans and polishes collector rings		"	
Checks and tightens pigtails and mechanical wire connections		"	
Replaces or repairs defective parts in motors and control devices		"	
Adjusts rotor and shaft alignment		"	
Reconditions or replaces contacts on relays and switches		"	
Replaces defective wiring and conduit		"	
Inspects exposed equipment for defective gaskets and seals		"	
Measures voltage, current, and power consumption		"	
Checks motor speeds		"	
Repairs and overhauls centrifugal, reciprocating, and diaphragm pumps:			
Troubleshoots and diagnoses malfunctions in pumps		"	
Installs, removes, and replaces pumps		"	
Disassembles and assembles pumps		"	
Inspects and measures bearings and bearing races for defects		"	
Repacks ball-thrust bearings, roller bearings, and guide bearings		"	
Cleans and inspects pump interior		"	
Checks stuffing box for free movement of gland and excessive leakage		"	

DEEP WELL INJECTION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repacks gland assembly and adjusts		See Chem Add	
Grinds and laps valves and valve seats		"	
Inspects impellers for deposits, scaling, and cavitation pits		"	
Dynamically balances impellers		"	
Checks and aligns drive system		"	
Fits replacement parts		"	
Repairs bent float rods, binding mechanical fittings		"	
Lubricates mechanical fittings		"	
Cleans and paints exterior housing		"	
Repairs and replaces pipes and pipe fittings:			
Troubleshoots and diagnoses nature and location of stoppages		"	
Removes and replaces sections of pipe, pipe fittings, and couplings		"	
Cuts and threads pipe		"	
Cleans pipe using mechanical and hydraulically propelled tools		"	
Replaces gaskets and seals on flange type joints		"	
Bends pipe and tubing		"	
Tests pipe systems for pressure capability and leaks		"	
May be required to repair and replace special purpose pipe and fittings of the following types:			
Glass		"	
Glass or plastic lined steel		"	

DEEP WELL INJECTION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Plastic and PVC		See Chem Add	
Aluminum		"	
Wood		"	
Vitrified tile		"	
Repairs and overhauls manual and automatic control valves:			
Troubleshoots and diagnoses malfunction in manual and controlled valves		"	
Installs, removes, and replaces valves		"	
Assembles and disassembles valves and control mechanisms		"	
Inspects and measures valve clearances		"	
Grinds, polishes, laps-in valves and valve seats		"	
Cleans and inspects valve actuating mechanisms		"	
Adjusts backlash in valve actuating mechanisms		"	
Lubricates valve actuating mechanisms		"	
Tests bellows and diaphragm actuators for leaks		"	
Calibrates valve position and control actuator		"	
Adjusts and replaces packing and seals		"	
Tests valves for complete opening and shut-off		"	
Tests functioning of control actuators (pneumatic, hydraulic, electrical, mechanical)		"	
Replaces worn or defective valve and actuator parts		"	
Repairs and overhauls mechanical drive systems:			
Troubleshoots and diagnoses malfunctions in mechanical systems		"	
Disassembles and assembles mechanical drive systems		"	

DEEP WELL INJECTION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Inspects and measures gear drives for wear and defects		See Chem Add	
Inspects chain drives, replaces defective links, adjusts tension		"	
Checks and measures sprocket alignment		"	
Inspects sprocket teeth for wear, hooks, and other defects		"	
Inspects and measures bearings and races for wear and defects		"	
Cleans and finishes moving parts to prevent freezing or binding		"	
Repacks bearings		"	
Fits and replaces parts showing excessive wear or defects		"	
Inspects and replaces water and oil seals as necessary		"	
Cleans and paints exposed surfaces		"	
Replaces drive belts, pulleys, and tensioning devices		"	

LAGOONING/COOLING PONDS/SOLAR EVAPORATION PONDS	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Operations			
Monitors and verifies the proper operation and condition of the following units of equipment:			
Concrete or masonry dams	OP	2	dly
Earthen dams or pits	"	2	dly
Masonry spillways or overflow pipes	"	2	1/Shift
Centrifugal and reciprocating pumps	"	2	"
Electric motors, relays, and circuit breakers/switches	"	2	"
Iron, steel, plastic, ceramic, and copper pipe and pipe fittings	"	1	"
Flow and level indicating devices	"	2	"
Manual and automatic control valves	"	2	"
Belt, chain, and gear drive mechanisms	"	2	"
Reads and interprets status and control instrumentation:			
Total suspended solids measuring units and recorders	"	2	"
Temperature measuring and recording devices	"	2	"
Flow meters and recorders	"	2	"
Conductivity recorders and meters	"	2	"
Activates and controls units of equipment:			
Switches to standby or parallel pumps	"	2	Var
Adjusts manual valves to control flow and retention time	"	3	"
Overrides automatic controls to correct in specific situations	"	3	"

LAGOONING/COOLING PONDS/SOLAR EVAPORATION PONDS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks flow time for individual lagoons or ponds using dye solutions	OP	2	1/Shift
Collects composite or grab samples for laboratory analysis	"	2	"
Preventive Maintenance Activities			
Services lagoons, cooling ponds, and evaporation ponds:			
Checks dams for leaks and deterioration	"	2	dly
Checks for debris which might block spillways or overflow pipes	"	2	"
Checks for signs of overtopping or overflow	"	2	"
Checks dam area for signs of seepage	"	2	"
Cleans growths and sediment from spillways	"	1	wkly
Checks for algae blooms and plant growths	"	2	"
Checks depth of sediment	"	2	mthly
Repairs earthen dams with clay and earth (with hand tools)	"	1	As Req
Repairs minor leaks in concrete or masonry dams with cement and mortar	"	2	"
Services electric motors and auxiliary equipment:			
Inspects motors for signs of overheating		See Chem Add	
Checks for excessive vibration or hum		"	
Checks wiring insulation		"	
Checks for dirt or moisture		"	
Checks drive coupling and motor mounts for play/loose fittings		"	

LAGOONING/COOLING PONDS/SOLAR EVAPORATION PONDS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks for sticking brushes or excessive arcing		See Chem Add	
Checks pilot lights and alarms		"	
Checks points and contacts for pitting		"	
Cleans and tightens electrical connections		"	
Checks and lubricates bearings		"	
Checks switches and circuit breakers for proper functioning		"	
Services centrifugal, reciprocating, and diaphragm pumps:			
Checks solenoid oiler flow; adjusts as necessary		"	
Checks oil level in ball bearing housing; fills as necessary		"	
Checks grease cup; maintains proper pressure		"	
Checks enclosed shaft bearings; refills oil cup as necessary		"	
Checks ball-thrust bearings; adds fresh grease as necessary		"	
Checks guide bearings; adds grease as necessary		"	
Drains and adds fresh lubricant to shaft bearings		"	
Flushes bearing housing and adds fresh grease		"	
Checks bearing temperatures; adjusts as necessary		"	
Checks stuffing boxes for leaks; tightens or repacks as necessary		"	
Checks water-seal systems for leaks; adjusts pressure as necessary		"	
Clean and paint pump casing		"	

LAGOONING/COOLING PONDS/SOLAR EVAPORATION PONDS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Check, clean, lubricate, and adjust float switch system		See Chem Add	
Inspect check valves for leaks		"	
Clean sediment and accumulated solids from sumps		"	
Check and clean strainers		"	
Services flow measuring devices:			
Cleans and flushes annular chambers		"	
Cleans and flushes piezometer pressure taps		"	
Cleans and dresses orifice plates		"	
Cleans and paints exterior		"	
Inspects interior for corrosion		"	
Purges connecting lines and fittings		"	
Services pipes and pipe fittings:			
Checks for leaks in pipes and pipe fittings		"	
Inspects for rust and corrosion		"	
Cleans and paints pipes and fittings		"	
Flushes dead-ends		"	
Checks and cleans sediment traps		"	
Checks and cleans wells and sumps		"	
Mechanically cleans pipes with augers and snakes		"	
Services manual and automatic control valves:			
Checks valves for leaks		"	
Inspects for rust and corrosion		"	
Checks actuating bellows for leaks		"	
Checks linkages for free movement		"	
Checks for complete opening and closing		"	

LAGOONING/COOLING PONDS/SOLAR EVAPORATION PONDS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks calibration		See Chem Add	
Lubricates control linkage		"	
Adjusts packing		"	
Cleans and paints exterior		"	
Cleans solenoid actuating mechanisms		"	
Services storage tanks, drums, and vessels:			
Checks for leaks		"	
Inspects for rust and corrosion		"	
Cleans and paints interior and exterior		"	
Removes accumulated deposits of sludge and sediment		"	
Services mechanical drive systems:			
Checks tension of flat and V-belt drives		"	
Checks and adjusts belt alignment		"	
Checks belts for wear		"	
Checks and adjusts chain drive slack		"	
Lubricates chain drive systems		"	
Checks lubricant levels in right-angle gear drives		"	
Checks lubricant levels in reduction gear boxes		"	
Drains and changes oil in sump systems		"	
Cleans and inspects variable speed belt drive systems		"	
Lubricates thrust and frame bearings for drive shafts		"	
Checks oil seals for leaks		"	
Lubricates pressure grease fittings		"	

LAGOONING/COOLING PONDS/SOLAR EVAPORATION PONDS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Corrective Maintenance Activities			
Repairs and cleans lagoons, cooling ponds, and evaporation ponds:			
Dredges sludge and sediment from lagoons and cooling ponds	Heavy Eq OP	3	As Req
Removes sludge cake with shovel and wheelbarrow	OP	1	"
Repairs and reinforces earthen dams (using heavy equipment)	Heavy Eq OP	3	"
Performs major repairs on faulty concrete or masonry dams	Cem Mason	3	"
Repairs and overhauls status and control instrumentation:			
Troubleshoots and diagnoses malfunctions in status and control instrumentation		See Chem Add	
Installs, removes, replaces status and control instrumentation		"	
Disassembles and reassembles status and control instrumentation		"	
Tests diaphragms, bourdon tubes, and bellows for leaks or defects		"	
Tests bimetallic strips and thermocouples for defects		"	
Tests electrical circuitry for shorts, open circuits, and resistance		"	
Cleans and adds mercury to manometers		"	
Cleans and sets contact points		"	
Cleans and checks knife edges		"	
Cleans and lubricates jeweled bearings		"	

LAGOONING/COOLING PONDS/SOLAR EVAPORATION PONDS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Blows down pressure lines to remove restrictions or stoppages		See Chem Add	
Cleans and checks orifices and nozzles		"	
Adjusts backlash in mechanical linkages		"	
Calibrates indicators and recorder pens against known standard		"	
Replaces worn or defective parts, seals, and bearings		"	
Repairs and overhauls electric motors and auxiliary equipment:			
Diagnoses and troubleshoots electrical malfunctions		"	
Installs, removes, replaces electric motors, wiring, and control devices		"	
Inspects and tests rotor and stator windings for shorts or open circuits		"	
Inspects commutator for wear, shorts, and signs of excessive heat		"	
Checks brushes for wear and proper spring tension		"	
Adjusts brushes to seat properly and prevent sticking		"	
Cleans, adjusts, and lubricates bearings		"	
Checks thermal switches, circuit breakers, and fuses		"	
Cleans and polishes collector rings		"	
Checks and tightens pigtails and mechanical wire connections		"	
Replaces or repairs defective parts in motors and control devices		"	

LAGOONING/COOLING PONDS/SOLAR EVAPORATION PONDS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Adjusts rotor and shaft alignment		See Chem Add	
Reconditions or replaces contacts on relays and switches		"	
Replaces defective wiring and conduit		"	
Inspects exposed equipment for defective gaskets and seals		"	
Measures voltage, current, and power consumption		"	
Checks motor speeds		"	
Repairs and overhauls centrifugal, reciprocating, and diaphragm pumps:			
Troubleshoots and diagnoses malfunctions in pumps		"	
Installs, removes, and replaces pumps		"	
Disassembles and assembles pumps		"	
Inspects and measures bearings and bearing races for defects		"	
Repacks ball-thrust bearings, roller bearings, and guide bearings		"	
Cleans and inspects pump interior		"	
Checks stuffing box for free movement of gland and excessive leakage		"	
Repacks gland assembly and adjusts		"	
Grinds and laps valves and valve seats		"	
Inspects impellers for deposits, scaling, and cavitation pits		"	
Dynamically balances impellers		"	
Checks and aligns drive system		"	
Fits replacement parts		"	
Repairs bent float rods, binding mechanical fittings		"	

LAGOONING/COOLING PONDS/SOLAR EVAPORATION PONDS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Lubricates mechanical fittings		See Chem Add	
Cleans and paints exterior housing		"	
Repairs and replaces pipes and pipe fittings:			
Troubleshoots and diagnoses nature and location of stoppages		"	
Removes and replaces sections of pipe, pipe fittings, and couplings		"	
Cuts and threads pipe		"	
Cleans pipe using mechanical and hydraulically propelled tools		"	
Replaces gaskets and seals on flange type joints		"	
Bends pipe and tubing		"	
Tests pipe systems for pressure capability and leaks		"	
May be required to repair and replace special purpose pipe and fittings of the following types:			
Glass		"	
Glass or plastic lined steel		"	
Plastic and PVC		"	
Aluminum		"	
Wood		"	
Vitrified tile		"	
Repairs and overhauls manual and automatic control valves:			
Troubleshoots and diagnoses malfunction in manual and controlled valves		"	

LAGOONING/COOLING PONDS/SOLAR EVAPORATION PONDS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Installs, removes, and replaces valves		See Chem Add	
Assembles and disassembles valves and control mechanisms		"	
Inspects and measures valve clearances		"	
Grinds, polishes, laps-in valves and valve seats		"	
Cleans and inspects valve actuating mechanisms		"	
Adjusts backlash in valve actuating mechanisms		"	
Lubricates valve actuating mechanisms		"	
Tests bellows and diaphragm actuators for leaks		"	
Calibrates valve position and control actuator		"	
Adjusts and replaces packing and seals		"	
Tests valves for complete opening and shut-off		"	
Tests functioning of control actuators (pneumatic, hydraulic, electrical, mechanical)		"	
Replaces worn or defective valve and actuator parts		"	
Repairs and overhauls mechanical drive systems:			
Troubleshoots and diagnoses malfunctions in mechanical systems		"	
Installs, removes, and replaces arms, paddles, and propellers		"	
Disassembles and assembles mechanical drive systems		"	
Inspects and measures gear drive for wear and defects		"	
Inspects chain drives, replaces defective links, adjusts tension		"	
Checks and measures sprocket alignment		"	

LAGOONING/COOLING PONDS/SOLAR EVAPORATION PONDS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Inspects sprocket teeth for wear, hooks, and other defects		See Chem Add	
Inspects and measures bearings and races for wear and defects		"	
Cleans and finishes moving parts to prevent freezing or binding		"	
Repacks bearings		"	
Fits and replaces parts showing excessive wear or defects		"	
Inspects and replaces water and oil seals as necessary		"	
Cleans and paints exposed surfaces		"	
Replaces drive belts, pulleys, and tensioning devices		"	

CENTRIFUGATION	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Operations			
Monitors and verifies proper operation and condition of the following units of equipment:			
Continuous horizontal centrifugals	OP	2	1/Shift
Suspended basket centrifugals	"	2	"
Undriven centrifugals	"	2	"
Electric motors, relays, and circuit breakers/switches	"	2	"
Pressure status and control instrumentation	"	2	"
Centrifugal and reciprocating pumps	"	2	"
Iron, steel, copper, and plastic pipe and pipe fittings	"	1	"
Manual and automatic control valves	"	2	"
Flow and liquid level instrumentation	"	2	"
Belt, chain, and gear drive mechanisms	"	2	"
Reads and interprets status and control instrumentation:			
Pressure gages and recorders	"	2	"
Flow meters and recorders	"	2	"
Conductivity recorders and meters	"	2	"
Pilot lamps and voltage/current meters and recorders	"	2	"
Activates and controls units of equipment:			
Adjusts and controls manual valves to achieve desired flow and retention time	"	2	As Req
Overrides automatic control valves to correct in emergency situations	"	3	"

CENTRIFUGATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Switches to standby or parallel pumps	OP	2	As Req
Regulates speed of centrifugal units	"	2	"
Removes and disposes of solids and slurries	"	1	"
Collects composite or grab samples for laboratory analysis	"	2	1/Shift
Preventive Maintenance Activities			
Services centrifugals:			
Replaces filter cloth and screen basket of centrifugals	"	2	"
Checks for worn plow tips and slingers	"	2	wkly
Cleans and lubricates moving parts	"	2	"
Cleans and paints exterior	"	1	yrly
Inspects drive belts for wear and proper tension	"	2	dly
Checks for rust and corrosion	"	2	wkly
Checks for leaks	"	2	dly
Services status and control instrumentation:			
Cleans and lubricates chart drive mechanisms	"	2	2/yr
Cleans electrical sensors	"	2	mthly
Checks electrical contacts, connections, and wiring	"	2	wkly
Checks pneumatic sensors for leaks	"	2	"
Checks zero or null setting on galvanometers and on pen recorders	"	2	"

CENTRIFUGATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks mechanical linkage for corrosion, rust, and freedom of movement	OP	2	wkly
Cleans indicator covers and glass viewing windows	"	2	mthly
Cleans recorder pens and checks for ink flow	"	2	dly
Checks indicated values against known standards (checks calibration)	"	3	mthly
Services electric motors and auxiliary equipment:			
Inspects motors for signs of overheating	"	2	dly
Checks for excessive vibration or hum	"	2	"
Checks wiring insulation	"	2	wkly
Checks for dirt or moisture	"	2	dly
Checks drive coupling and motor mounts for play/loose fittings	"	2	"
Checks for sticking brushes or excessive arcing	"	2	"
Checks pilot lights and alarms	"	2	1/Shift
Checks points and contacts for pitting	"	2	mthly
Cleans and tightens electrical connections	"	2	"
Checks and lubricates bearings	"	1	wkly
Checks switches and circuit breakers for proper functioning	"	2	dly
Services centrifugal, reciprocating, and diaphragm pumps:			
Checks solenoid oiler flow; adjusts as necessary	"	2	wkly
Checks oil level in ball bearing housing; fills as necessary	"	1	dly
Checks grease cup; maintains proper pressure	"	2	"
Checks enclosed shaft bearings; refills oil cup as necessary	"	2	"

CENTRIFUGATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks ball-thrust bearings; adds fresh grease as necessary	OP	2	mthly
Checks guide bearings; adds grease as necessary	"	2	wkly
Drains and adds fresh lubricant to shaft bearings	"	2	mthly
Flushes bearing housing and adds fresh grease	"	2	4/yr
Checks bearing temperatures; adjusts as necessary	"	2	wkly
Checks stuffing boxes for leaks; tightens or repacks as necessary	"	2	dly
Checks water-seal systems for leaks; adjusts pressure as necessary	"	2	"
Clean and paint pump casing	"	1	"
Check, clean lubricate, and adjust float switch system	"	2	wkly
Inspect check valves for leaks	"	2	dly
Clean sediment and accumulated solids from sumps	"	1	mthly
Check and clean strainers	"	1	dly
Services flow measuring devices:			
Cleans and flushes annular chambers	"	2	mthly
Cleans and flushes piezometer pressure taps	"	2	"
Cleans and dresses orifice plates	"	2	2/yr
Cleans and paints exterior	"	1	yrly
Inspects interior for corrosion	"	2	mthly
Purges connecting lines and fittings	"	2	wkly
Services pipes and pipe fittings:			
Checks for leaks in pipes and pipe fittings	"	1	"
Inspects for rust and corrosion	"	1	"
Cleans and paints pipes and fittings	"	1	yrly

CENTRIFUGATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Flushes dead-ends	OP	2	mthly
Checks and cleans sediment traps	"	1	wkly
Checks and cleans wells and sumps	"	1	"
Mechanically cleans pipes with augers and snakes	"	2	As Req
Services manual and automatic control valves:			
Checks valves for leaks	"	2	dly
Inspects for rust and corrosion	"	2	wkly
Checks actuating bellows for leaks	"	2	dly
Checks linkages for free movement	"	2	"
Checks for complete opening and closing	"	2	"
Checks calibration	"	3	mthly
Lubricates control linkage	"	2	wkly
Adjusts packing	"	2	"
Cleans and paints exterior	"	1	yrly
Cleans solenoid actuating mechanisms	"	2	dly
Services storage tanks, drums, and vessels:			
Checks for leaks	"	1	"
Inspects for rust and corrosion	"	1	wkly
Cleans and paints interior and exterior	"	1	yrly
Removes accumulated deposits of sludge and sediment	"	1	wkly
Services mixing and blending equipment:			
Cleans deposits from paddles, arms, and propellers	"	1	"
Inspects for rust and corrosion	"	1	"
Inspects mechanical drive functioning	"	2	"
Lubricates mechanical drive system	"	2	"

CENTRIFUGATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Paints and protects exposed surfaces	OP	1	yrly
Checks for homogeneity of mixed substances	"	2	dly
Checks speed of mixing or blending	"	2	"
Services mechanical drive systems:			
Checks tension of flat and V-belt drives	"	2	"
Checks and adjusts belt alignment	"	2	"
Checks belts for wear	"	2	wkly
Checks and adjusts chain drive slack	"	2	"
Lubricates chain drive systems	"	2	"
Checks lubricant levels in right-angle gear drives	"	2	"
Checks lubricant levels in reduction gear boxes	"	2	"
Drains and changes oil in sump systems	"	2	mthly
Cleans and inspects variable speed belt drive systems	"	2	wkly
Lubricates thrust and frame bearings for drive shafts	"	2	"
Checks oil seals for leaks	"	2	dly
Lubricates pressure grease fittings	"	2	wkly
Corrective Maintenance Activities			
Repairs and overhauls centrifugals:			
Troubleshoots and diagnoses malfunctions in centrifugals	Mech Main	3	As Req
Installs, removes, and replaces screen and solid bowls	"	3	"
Removes and replaces worn or defective plow tips and slingers	"	3	"

CENTRIFUGATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repairs and replaces basket liners, brakes, and baskets	Mech Main	3	As Req
Replaces worn or defective bearings, seals, and gaskets	"	3	"
Repairs and overhauls status and control instrumentation:			
Troubleshoots and diagnoses malfunctions in status and control instrumentation	Ins Repmn	3	"
Installs, removes, replaces status and control instrumentation	"	3	"
Disassembles and reassembles status and control instrumentation	"	3	"
Tests diaphragms, bourdon tubes, and bellows for leaks or defects	"	3	"
Tests bimetallic strips and thermocouples for defects	"	3	"
Tests electrical circuitry for shorts, open circuits, and resistance	"	3	"
Cleans and adds mercury to manometers	"	3	"
Cleans and sets contact points	"	3	"
Cleans and checks knife edges	"	3	"
Cleans and lubricates jeweled bearings	"	3	"
Blows down pressure lines to remove restrictions or stoppages	"	3	"
Cleans and checks orifices and nozzles	"	3	"
Adjusts backlash in mechanical linkages	"	3	"
Calibrates indicators and recorder pens against known standard	"	3	"
Replaces worn or defective parts, seals, and bearings	"	3	"

CENTRIFUGATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repairs and overhauls electric motors and auxiliary equipment:			
Diagnoses and troubleshoots electrical malfunctions	Elec	3	As Req
Installs, removes, replaces electric motors, wiring, and control devices	"	3	"
Inspects and tests rotor and stator windings for shorts or open circuits	"	3	"
Inspects commutator for wear, shorts, and signs of excessive heat	"	3	"
Checks brushes for wear and proper spring tension	"	3	"
Adjusts brushes to seat properly and prevent sticking	"	3	"
Cleans, adjusts, and lubricates bearings	"	3	"
Checks thermal switches, circuit breakers, and fuses	"	3	"
Cleans and polishes collector rings	"	3	"
Checks and tightens pigtails and mechanical wire connections	"	3	"
Replaces or repairs defective parts in motors and control devices	"	3	"
Adjusts rotor and shaft alignment	"	3	"
Reconditions or replaces contacts on relays and switches	"	3	"
Replaces defective wiring and conduit	"	3	"
Inspects exposed equipment for defective gaskets and seals	"	3	"
Measures voltage, current, and power consumption	"	3	"
Checks motor speeds	"	3	"

CENTRIFUGATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repairs and overhauls centrifugal, reciprocating, and diaphragm pumps:			
Troubleshoots and diagnoses malfunctions in pumps	Pump Serv	3	As Req
Installs, removes, and replaces pumps	"	3	"
Disassembles and assembles pumps	"	3	"
Inspects and measures bearings and bearing races for defects	"	3	"
Repacks ball-thrust bearings, roller bearings, and guide bearings	"	3	"
Cleans and inspects pump interior	"	3	"
Checks stuffing box for free movement of gland and excessive leakage	"	3	"
Repacks gland assembly and adjusts	"	3	"
Grinds and laps valves and valve seats	"	3	"
Inspects impellers for deposits, scaling, and cavitation pits	"	3	"
Dynamically balances impellers	"	3	"
Checks and aligns drive system	"	3	"
Fits replacement parts	"	3	"
Repairs bent float rods, binding mechanical fittings	"	3	"
Lubricates mechanical fittings	"	3	"
Cleans and paints exterior housing	"	1	"
Repairs and replaces pipes and pipe fittings:			
Troubleshoots and diagnoses nature and location of stoppages	Pipe Ftr	3	"
Removes and replaces sections of pipe, pipe fittings, and couplings	"	3	"
Cuts and threads pipe	"	3	"

CENTRIFUGATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Cleans pipe using mechanical and hydraulically propelled tools	Pipe Ftr	3	As Req
Replaces gaskets and seals on flange type joints	"	3	"
Bends pipe and tubing	"	3	"
Tests pipe systems for pressure capability and leaks	"	3	"
May be required to repair and replace special purpose pipe and fittings of the following types:			
Glass	"	3	"
Glass or plastic lined steel	"	3	"
Plastic and PVC	"	3	"
Aluminum	"	3	"
Wood	"	3	"
Vitrified tile	"	3	"
Repairs and overhauls manual and automatic control valves:			
Troubleshoots and diagnoses malfunctions in manual and controlled valves	Ins Repmn	3	"
Installs, removes, and replaces valves	"	3	"
Assembles and disassembles valves and control mechanisms	"	3	"
Inspects and measures valve clearances	"	3	"
Grinds, polishes, laps in valves and valve seats	"	3	"
Cleans and inspects valve actuating mechanisms	"	3	"
Adjusts backlash in valve actuating mechanisms	"	3	"
Lubricates valve actuating mechanisms	"	3	"

CENTRIFUGATION (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Tests bellows and diaphragm actuators for leaks	Ins Repmn	3	As Req
Calibrates valve position and control actuator	"	3	"
Adjusts and replaces packing and seals	"	3	"
Tests valves for complete opening and shut-off	"	3	"
Tests functioning of control actuators (pneumatic, hydraulic, electrical, mechanical)	"	3	"
Replaces worn or defective valve and actuator parts	"	3	"
Repairs and overhauls storage tanks, drums, and vessels:			
Repairs leaks and defective portions of steel storage facilities	Mech Main	3	"
Repairs leaks and defective portions of lined steel storage facilities	"	3	"
Repairs leaks and defective portions of wood storage facilities	"	3	"
Repairs leaks and defective portions of concrete storage facilities	"	3	"
Diagnoses cause of rust, corrosion, and leaks	"	3	"

COOLING TOWERS	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Operations			
Monitors and verifies proper operation and condition of the following units of equipment:			
Forced draft cooling towers	OP	2	1/Shift
Convection cooling towers	"	2	"
Centrifugal and reciprocating pumps	"	2	"
Electric motors, relays, and circuit breakers/ switches	"	2	"
Iron, steel, copper, plastic, and ceramic pipe and pipe fittings	"	1	"
Temperature measuring and recording devices	"	2	"
Belt, chain, and gear drive mechanisms	"	2	"
Manual and automatic control valves	"	2	"
Flow rate indicators and recorders	"	2	"
pH meters and recorders	"	2	"
Conductivity meters and recorders	"	2	"
Reads and interprets status and control instrumentation:			
Temperature indicators and recorders	"	2	"
pH meters and recorders	"	2	"
Flow meters and control instrumentation	"	2	"
Conductivity recorders and meters	"	2	"
Pilot lamps and alarm devices	"	2	"
Activates and controls units of equipment:			
Switches to standby or parallel pumps	"	2	"
Adjusts manual valves to control flow and recirculation rate	"	2	As Req
Activates forced draft fans and blowers	"	2	"

COOLING TOWERS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Collects composite or grab samples of blowdown for laboratory analysis	OP	2	1/Shift
Preventive Maintenance Activities			
Services cooling towers:			
Checks wood baffles for rotting and general deterioration	"	2	"
Cleans growths and heavy deposits from baffles	"	1	As Req
Cleans and inspects water distribution system	"	2	"
Inspects condition of tower structural members	"	2	mthly
Services status and control instrumentation:			
Cleans and lubricates chart drive mechanisms	See Chem Add		
Cleans electrical sensors		"	
Checks electrical contacts, connections, and wiring		"	
Checks pneumatic sensors for leaks		"	
Checks zero or null setting on galvanometers and pen recorders		"	
Checks mechanical linkage for corrosion, rust, and freedom of movement		"	
Cleans indicator covers and glass viewing windows		"	
Cleans recorder pens and checks for ink flow		"	
Checks indicated values against known standards (checks calibration)		"	

COOLING TOWERS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Services electric motors and auxiliary equipment:			
Inspects motors for signs of overheating		See Chem Add	
Checks for excessive vibration or hum		"	
Checks wiring insulation		"	
Checks for dirt or moisture		"	
Checks drive coupling and motor mounts for play/loose fittings		"	
Checks for sticking brushes or excessive arcing		"	
Checks pilot lights and alarms		"	
Checks points and contacts for pitting		"	
Cleans and tightens electrical connections		"	
Checks and lubricates bearings		"	
Checks switches and circuit breakers for proper functioning		"	
Services centrifugal, reciprocating, and diaphragm pumps:			
Checks solenoid oiler flow; adjusts as necessary		"	
Checks oil level in ball bearing housing; fills as necessary		"	
Checks grease cup; maintains proper pressure		"	
Checks enclosed shaft bearings, refills oil cup as necessary		"	
Checks ball-thrust bearings, adds fresh grease as necessary		"	
Checks guide bearings; adds grease as necessary		"	
Drains and adds fresh lubricant to shaft bearings		"	
Flushes bearing housing and adds fresh grease		"	
Checks bearing temperatures; adjusts as necessary		"	

COOLING TOWERS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Checks stuffing boxes for leaks; tightens or repacks as necessary		See Chem Add	
Checks water-seal systems for leaks, adjusts pressure as necessary		"	
Clean and paint pump casing		"	
Check, clean, lubricate, and adjust float switch system		"	
Inspect check valves for leaks		"	
Clean sediment and accumulated solids from sumps		"	
Check and clean strainers		"	
Services flow measuring devices:			
Cleans and flushes annular chambers		"	
Cleans and flushes piezometer pressure taps		"	
Cleans and dresses orifice plates		"	
Cleans and paints exterior		"	
Inspects interior for corrosion		"	
Purges connecting lines and fittings		"	
Services pipes and pipe fittings:			
Checks for leaks in pipes and pipe fittings		"	
Inspects for rust and corrosion		"	
Cleans and paints pipes and fittings		"	
Flushes dead-ends		"	
Checks and cleans sediment traps		"	
Mechanically cleans pipes with augers and snakes		"	

COOLING TOWERS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Services manual and automatic control valves:			
Checks valves for leaks		See Chem Add	
Inspects for rust and corrosion		"	
Checks actuating bellows for leaks		"	
Checks linkages for free movement		"	
Checks for complete opening and closing		"	
Checks calibration		"	
Lubricates control linkage		"	
Adjusts packing		"	
Cleans and paints exterior		"	
Cleans solenoid actuating mechanisms		"	
Services storage tanks, drums, and vessels:			
Checks for leaks		"	
Inspects for rust and corrosion		"	
Cleans and paints interior and exterior		"	
Removes accumulated deposits of sludge and sediment		"	
Services mechanical drive systems:			
Checks tension of flat and V-belt drives		"	
Checks and adjusts belt alignment		"	
Checks belts for wear		"	
Checks and adjusts chain drive slack		"	
Lubricates chain drive systems		"	
Checks lubricant levels in right-angle gear drives		"	
Checks lubricant levels in reduction gear boxes		"	
Drains and changes oil in sump systems		"	

COOLING TOWERS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Cleans and inspects variable speed belt drive systems		See Chem Add	
Lubricates thrust and frame bearings for drive shafts		"	
Checks oil seals for leaks		"	
Lubricates pressure grease fittings		"	
Corrective Maintenance Activities			
Repairs and rebuilds wooden cooling towers:			
Erects scaffolding	Main Carp	3	As Req
Dissassembles and assembles cooling tower structure	"	3	"
Cuts and fits replacement baffles and structural members	"	3	"
Repairs and overhauls status and control instrumentation:			
Troubleshoots and diagnoses malfunctions in status and control instrumentation		See Chem Add	
Installs, removes, replaces status and control instrumentation		"	
Disassembles and reassembles status and control instrumentation		"	
Tests diaphragms, bourdon tubes, and bellows for leaks or defects		"	
Tests bimetallic strips and thermocouples for defects		"	
Tests electrical circuitry for shorts, open circuits, and resistance		"	

COOLING TOWERS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Cleans and adds mercury to manometers		See Chem Add	
Cleans and sets contact points		"	
Cleans and checks knife edges		"	
Cleans and lubricates jeweled bearings		"	
Blows down pressure lines to remove restrictions or stoppages		"	
Cleans and checks orifices and nozzles		"	
Adjusts backlash in mechanical linkages		"	
Calibrates indicators and recorder pens against known standard		"	
Replaces worn or defective parts, seals, and bearings		"	
Repairs and overhauls electric motors and auxiliary equipment:			
Diagnoses and troubleshoots electrical malfunctions		"	
Installs, removes, replaces electric motors, wiring, and control devices		"	
Inspects and tests rotor and stator windings for shorts or open circuits		"	
Inspects commutator for wear, shorts, and signs of excessive heat		"	
Checks brushes for wear and proper spring tension		"	
Adjusts brushes to seat properly and prevent sticking		"	
Cleans, adjusts, and lubricates bearings		"	
Checks thermal switches, circuit breakers, and fuses		"	
Cleans and polishes collector rings		"	

COOLING TOWERS (cont.)	OCCUPATONAL AREA	SKILL LEVEL	FREQUENCY f
Checks and tightens pigtails and mechanical wire connections		See Chem Add	
Replaces or repairs defective parts in motors and control devices		"	
Adjusts rotor and shaft alignment		"	
Reconditions or replaces contacts on relays and switches		"	
Replaces defective wiring and conduit		"	
Inspects exposed equipment for defective gaskets and seals		"	
Measures voltage, current, and power consumption		"	
Checks motor speeds		"	
Repairs and overhauls centrifugal, reciprocating, and diaphragm pumps:			
Troubleshoots and diagnoses malfunctions in pumps		"	
Installs, removes, and replaces pumps		"	
Disassembles and assembles pumps		"	
Inspects and measures bearings and bearing races for defects		"	
Repacks ball-thrust bearings, roller bearings, and guide bearings		"	
Cleans and inspects pump interior		"	
Checks stuffing box for free movement of gland and excessive leakage		"	
Repacks gland assembly and adjusts		"	
Grinds and laps valves and valve seats		"	
Inspects impellers for deposits, scaling and cavitation pits		"	

COOLING TOWERS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Dynamically balances impellers		See Chem Add	
Checks and aligns drive system		"	
Fits replacement parts		"	
Repairs bent float rods, binding mechanical fittings		"	
Lubricates mechanical fittings		"	
Cleans and paints exterior housing		"	
Repairs and replaces pipes and pipe fittings:			
Troubleshoots and diagnoses nature and location of stoppages		"	
Removes and replaces sections of pipe, pipe fittings, and couplings		"	
Cuts and threads pipe		"	
Cleans pipe using mechanical and hydraulically propelled tools		"	
Replaces gaskets and seals on flange type joints		"	
Bends pipe and tubing		"	
Tests pipe systems for pressure capability and leaks		"	
May be required to repair and replace special purpose pipe and fittings of the following types:			
Glass		"	
Glass or plastic lined steel		"	
Plastic and PVC		"	
Aluminum		"	
Wood		"	
Vitrified tile		"	

COOLING TOWERS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Repairs and overhauls manual and automatic control valves:			
Troubleshoots and diagnoses malfunction in manual and controlled valves		See Chem Add	
Installs, removes, and replaces valves		"	
Assembles and disassembles valves and control mechanisms		"	
Inspects and measures valve clearances		"	
Grinds, polishes, laps-in valves and valve seats		"	
Cleans and inspects valve actuating mechanisms		"	
Adjusts backlash in valve actuating mechanisms		"	
Lubricates valve actuating mechanisms		"	
Tests bellows and diaphragm actuators for leaks		"	
Calibrates valve position and control actuator		"	
Adjusts and replaces packing and seals		"	
Tests valves for complete opening and shut-off		"	
Tests functioning of control actuators (pneumatic, hydraulic, electrical, mechanical)		"	
Replaces worn or defective valve and actuator parts		"	
Repairs and overhauls storage tanks, drums, and vessels:			
Repairs leaks and defective portions of steel storage facilities		"	
Repairs leaks and defective portions of lined steel storage facilities		"	
Repairs leaks and defective portions of wood storage facilities		"	
Repairs leaks and defective portions of concrete storage facilities		"	

COOLING TOWERS (cont.)	OCCUPATIONAL AREA	SKILL LEVEL	FREQUENCY f
Diagnoses cause of rust, corrosion, and leaks		See Chem Add	
Repairs and overhauls mechanical drive systems:			
Troubleshoots and diagnoses malfunctions in mechanical systems		"	
Disassembles and assembles mechanical drive systems		"	
Inspects and measures gear drives for wear and defects		"	
Inspects chain drives, replaces defective links, adjusts tension		"	
Checks and measures sprocket alignment		"	
Inspects sprocket teeth for wear, hooks, and other defects		"	
Inspects and measures bearings and races for wear and defects		"	
Cleans and finishes moving parts to prevent freezing or binding		"	
Repacks bearings		"	
Fits and replaces parts showing excessive wear or defects		"	
Inspects and replaces water and oil seals as necessary		"	
Cleans and paints exposed surfaces		"	
Replaces drive belts, pulleys, and tensioning devices		"	

APPENDIX E

COSTS OF UNIT WASTEWATER TREATMENT PRACTICES

Neutralization
Deep Well Disposal
Reverse Osmosis
Electrodialysis
Ion Exchange
Multiple Effect Evaporation
Solar Evaporation
Cooling Towers

An envelope of extreme values of TDS and flow rate that have been considered for the subsequent cost calculations are shown in Figure 1. The following are the combinations within the triangle of flow, acidity, suspended and dissolved solids chosen for the study:

Flow rate	0.5, 1.0, 10.0, 50.0 mgd
Acidity	500, 1000, 20,000 mg/l (as $CaCO_3$)
Suspended solids	100, 500 mg/l
TDS	3000, 30,000, 150,000 mg/l

The flow sheet used for the cost calculations is shown in Figure 2. When neutralization is not required, the neutralization portion will be bypassed.

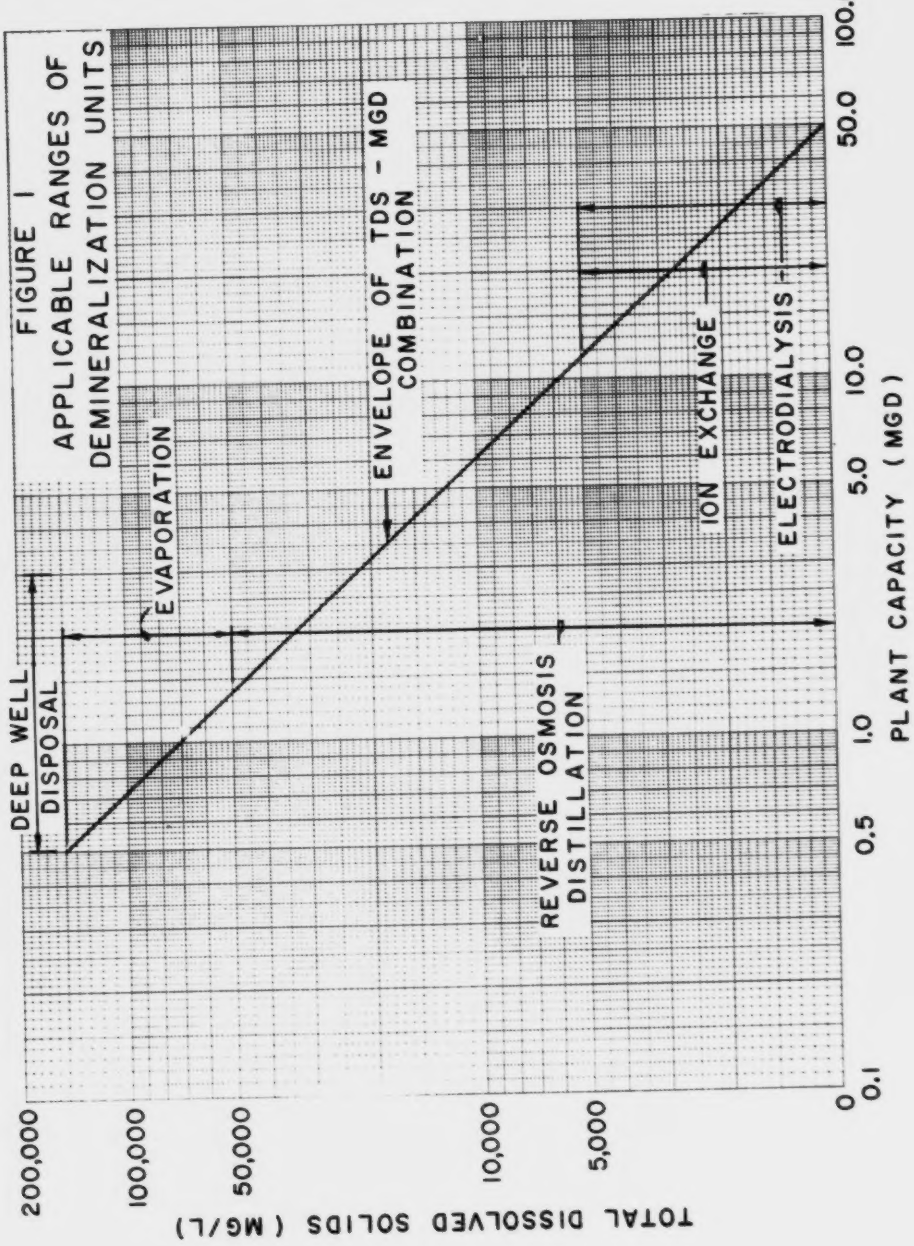


FIGURE 1
APPLICABLE RANGES OF DEMINERALIZATION UNITS

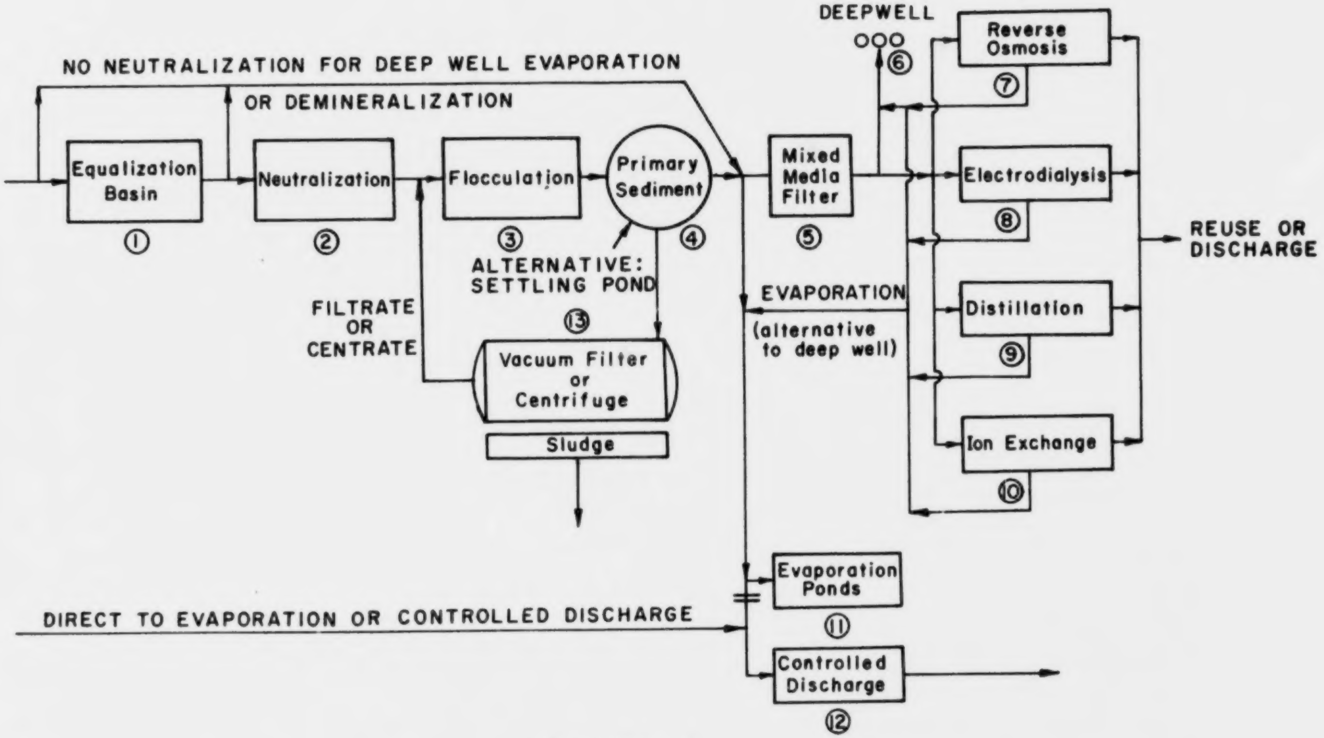

NO NEUTRALIZATION FOR DEEP WELL EVAPORATION
OR DEMINERALIZATION
Equalization Basin
①
Neutralization
②
Flocculation
③
Primary Sediment
④
ALTERNATIVE: SETTLING POND
FILTRATE OR CENTRATE
⑬
Vacuum Filter or Centrifuge
Sludge
Mixed Media Filter
⑤
DEEPWELL
⑥
EVAPORATION
(alternative to deep well)
Reverse Osmosis
⑦
Electrodialysis
⑧
Distillation
⑨
Ion Exchange
⑩
REUSE OR DISCHARGE
DIRECT TO EVAPORATION OR CONTROLLED DISCHARGE
Evaporation Ponds
⑪
Controlled Discharge
⑫

FIGURE 2

SCHEMATIC LAYOUT OF TREATMENT PLANT FOR WASTES FROM THE INORGANIC CHEMICAL INDUSTRY SHOWING VARIOUS POSSIBLE COMBINATIONS OF UNITS

NEUTRALIZATION

Neutralization of inorganic industrial wastes usually implies the use of some form of lime for the neutralization of acidic wastes or sulfuric acid for the neutralization of alkaline wastes. Acidic wastes are more prevalent and neutralization presents more of a problem with such wastes. All forms of inexpensive neutralizing material produces sludge which is difficult to dewater. For large scale plants, economy requires the use of some form of lime or limestone for treatment. Hydrated lime has been used extensively for neutralization of acidic wastes but recent studies (1) seem to indicate that greater economy could be achieved by the use of limestone, both from the viewpoint of lower cost of the alkali combined with a lower cost of sludge dewatering (2). Few cost figures are available for limestone treatment facilities, and for the purpose of this study, only hydrated lime treatment will be considered.

Neutralization with lime combined with aeration will remove iron as a necessary consequence since the solubility of ferric ions decreases rapidly above a pH of 3.0. Manganese, alumina, and silica, as well as many of the heavy metal ions, also are removed by lime neutralization resulting in a decrease in total hardness.

The capital costs were calculated for a flow sheet shown in Figure 3. Equalization capacity is required to supply a constant flow of waste to the flash mixer. Lime from the lime storage tank is fed into the slaker together with some clarified effluent. Lime slurry from the slaker is added to the waste stream in a flash mixer. After flash mixing, the mixture is flocculated and aerated. Next the waste is thickened in a clarifier-thickener or in a sludge settling pond. The underflow from the thickeners with 2% to 3% solids may be passed on to a vacuum filter

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(1) Mihok, E. A., et al "Mine Water Research-The Limestone Neutralization Process, U.S. Bureau of Mines R.I. 7191, September, 1968.

(2) Rice & Company, "Engineering Economic Studies of Mine Drainage Control Techniques," Appendix B to Acid Mine Drainage in Appalachia, A Report by the Appalachian Regional Commission.

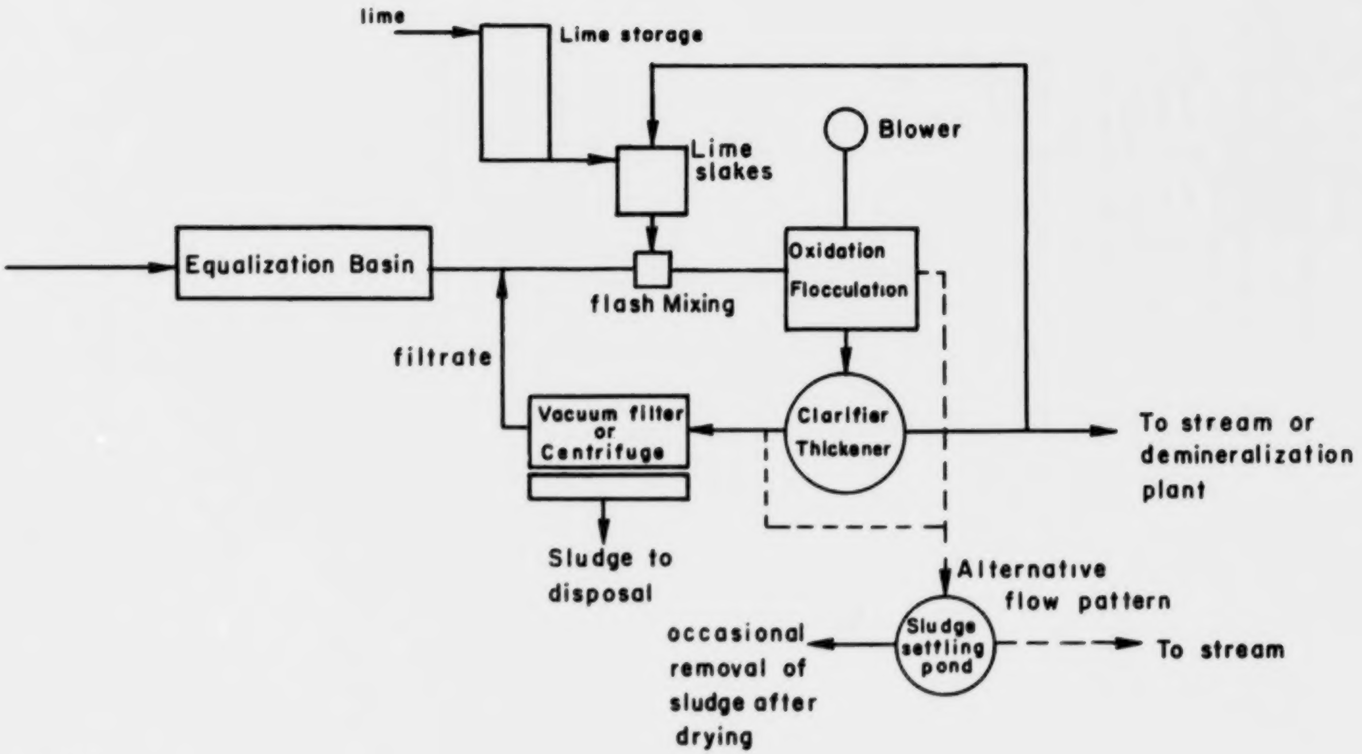

lime
Lime storage
Lime slakes
Blower
Equalization Basin
flash Mixing
Oxidation
Flocculation
filtrate
Vacuum filter or Centrifuge
Clarifier
Thickener
To stream or demineralization plant
Sludge to disposal
Alternative flow pattern
occasional removal of sludge after drying
Sludge settling pond
To stream

FIGURE 3
FLOW SHEET FOR NEUTRALIZATION PLANT

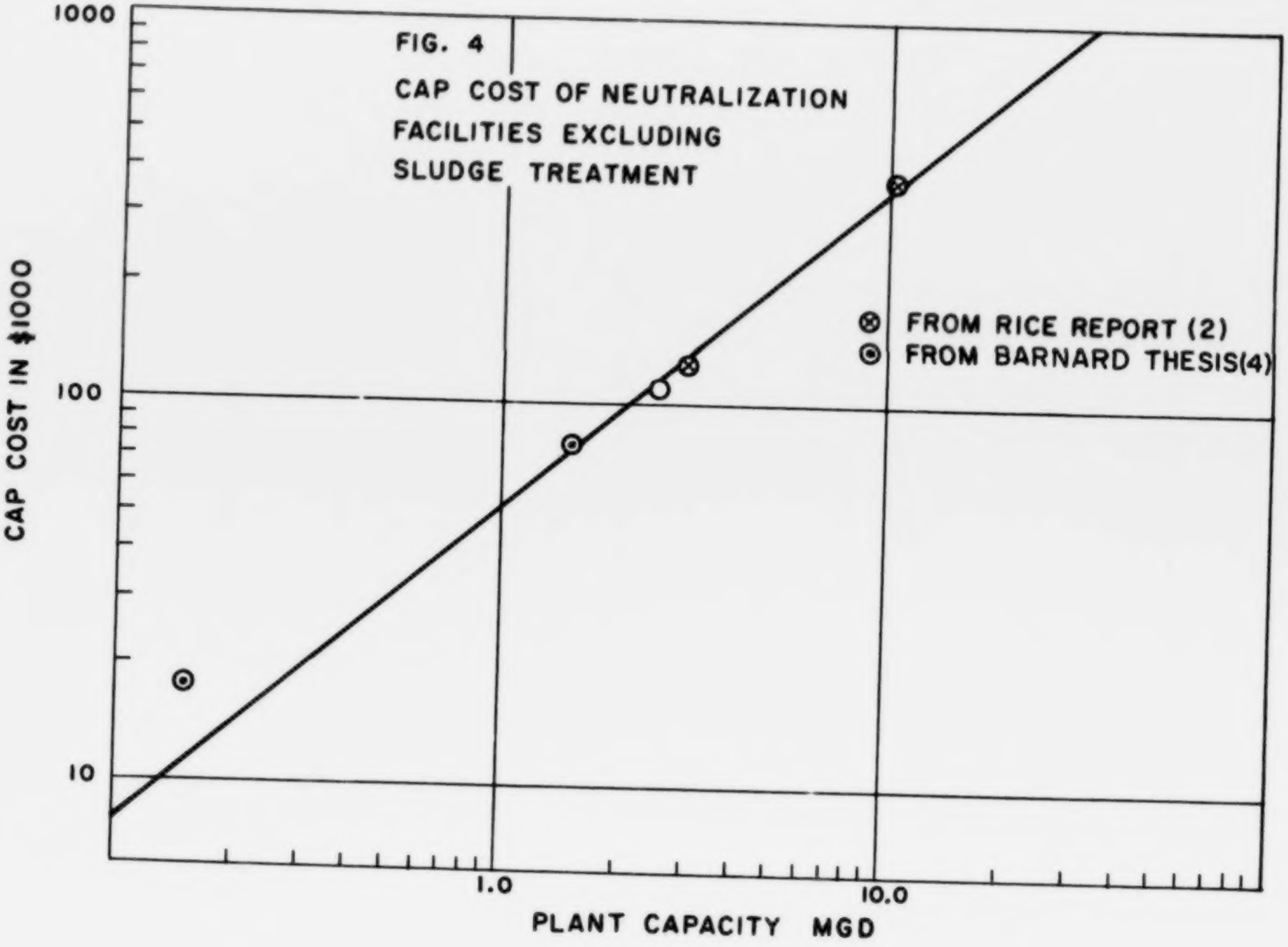


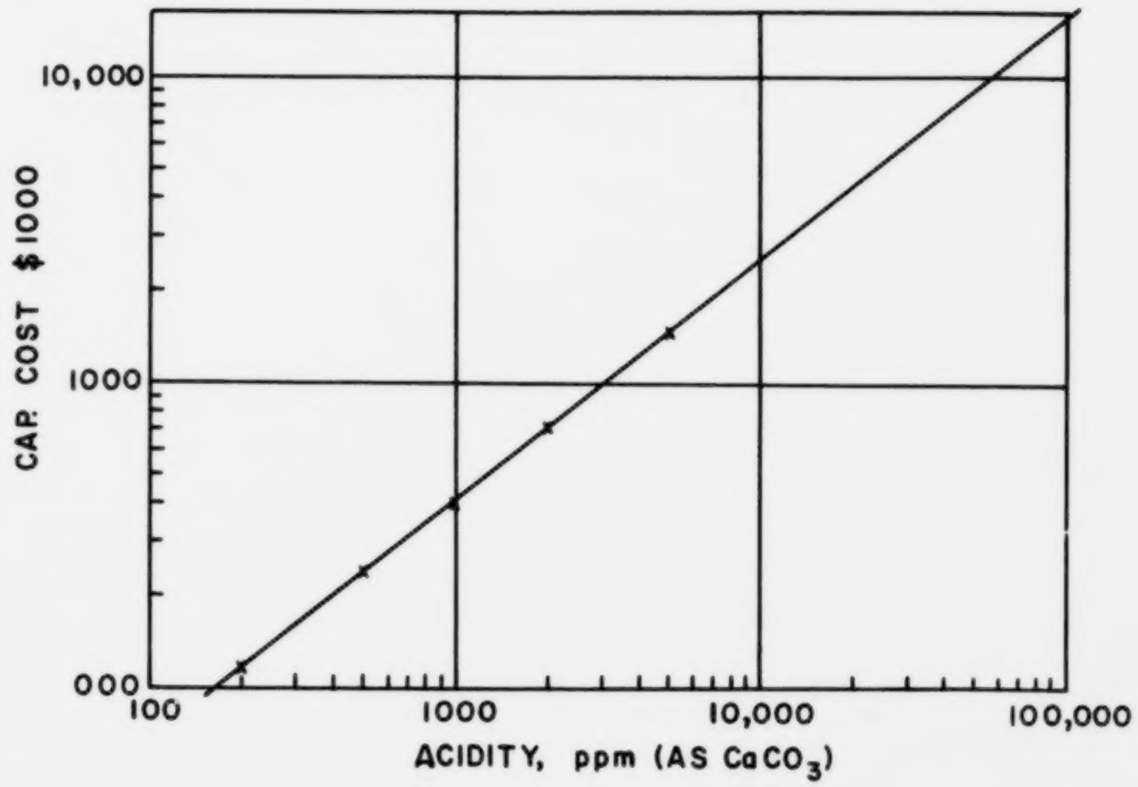
FIG. 4

CAP COST OF NEUTRALIZATION
FACILITIES EXCLUDING
SLUDGE TREATMENT

HYDRATED LIME TREATMENT PLANT

FIGURE 5

CAP. COST. VS ACIDITY FOR 1 MGD PLANT (INCLUDING SLUDGE DISPOSAL)
(FROM OPERATION YELLOWBOY) (2)



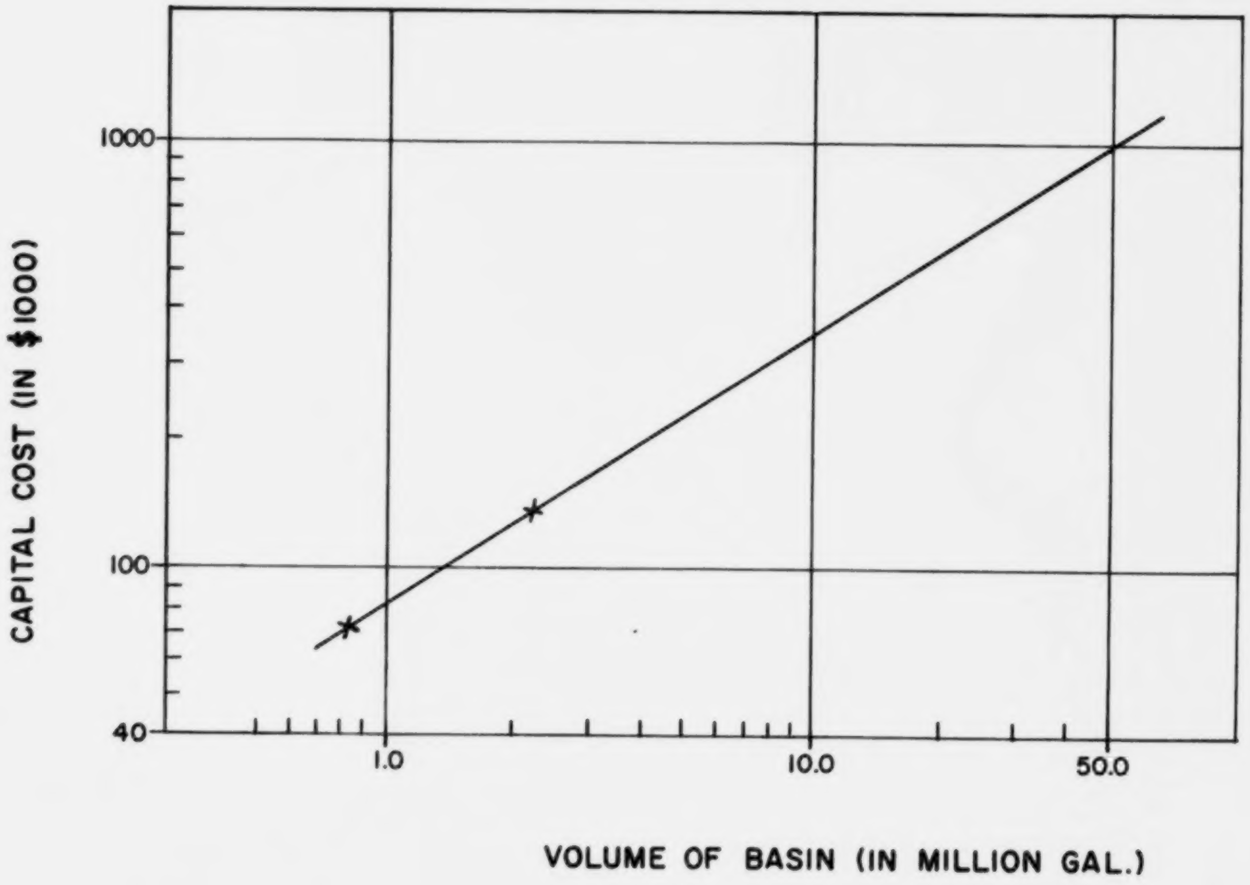


FIG. 6 CAPITAL COST OF EQUALIZATION BASINS REF. (3)

or a centrifuge for dewatering or may be discharged to a dewatering pond. Sludge will be dewatered mechanically to approximately 20% solids at which consistency it can be trucked to disposal. If abundant land is available, the waste will be discharged from the flocculator directly into a settling pond. If land is scarce but available within pumping distance, only the thickened sludge will be settled in a pond.

Costs for hydrated lime treatment of acid drainage including sludge disposal by thickening and disposal of the slurry in ponds are presented in a report on the economics of acid mine drainage (2). These cost curves show a decrease in the unit capital cost of neutralization facilities with increase of acidity, but no such decrease in unit cost with increase in the volume of waste treated daily. This is contrary to previous findings (4) that the overall cost increase is proportional to flow rate to the power of 0.83 (see Figure 4). Combining these two values, the general overall cost for neutralization, thickening and sludge holding ponds can then be expressed as:

$$\text{Capital Cost (in \$1000)} = 172\ Q^{0.83} A^{0.79} \quad \text{(see Figure 5)}$$

where

Q = flow rate in mgd
A = acidity in mg/l

From available cost curves for (1) the equalization basin, (2) lime plant, mixes and flocculator (3) the clarifier thickener and (4) the vacuum filter or centrifuge, it was also possible to synthesize the cost for full sludge dewatering.

The cost curve for equalization basins (shown in Figure 6) is based on findings by Chow (3) and additional costs determined by Barnard (4).

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(2) Rice, ibid

(3) Chow, C. S., Malina, J. F. and Eckenfelder, W. W., "Effluent Quality and Treatment Economics," Report published by the Center for Research in Water Resources Technical Report EHE 07-6801, CRWR 28, The University of Texas at Austin.

(4) Barnard, J. L., "Treatment Cost Relationships for Wastes from the Organic Chemical Industry," M.S. Thesis, The University of Texas at Austin, June, 1969.

The cost curve for the lime plant mixer and flocculator is based on costs extracted by Barnard (4) and additional costs obtained from Operation Yellow Boy (2). These curves shown little variation with acidity which influences mainly the sludge handling units, but they are dependent on the plant size.

Costs for the clarifier thickener were based mainly on flow since clarification and thickening is combined into one unit. Clarification requires a minimum overflow rate for effluent control and this will determine the size of the unit. The amount of thickening obtained is then calculated from zone settling considerations to determine the consistency of the thickener underflow. Costs were obtained from the Mine Drainage Report (2) and calculated from parameters obtained from a laboratory study of neutralized acid wastes.

The size of the clarifier itself is based on an overflow rate of 700 gpd/ft^2. In order to produce an effluent suitable for further use or treatment, it will be necessary to use polymers to reduce the suspended solids in the effluent and to filter the effluent. The thickener design was based on values from laboratory studies (5) as shown in Figures 7 and 8.

The design is based on the following mathematical model by Edde and Eckenfelder (6):

$$\frac{Cu}{Ci} - 1 = \frac{k_B}{(ML)^n}$$

where

Cu = solids concentration of the underflow in mg/l
Ci = influent solids concentration in mg/l
k_B = constant depending on Ci as shown in Figure 8
ML = mass loading in lbs. solids per day/sq. ft. of tank surface

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(2) Rice, ibid

(4) Barnard, ibid

(5) Atlas Chemicals, Marshall, Texas, Private Report.

(6) Edde, H., and Eckenfelder, W. W., "Theoretical Concept of Gravity Sludge Thickening," Presented at 40th Annual Conference of the Water Pollution Control Federation, New York, New York, October 8, 1967.

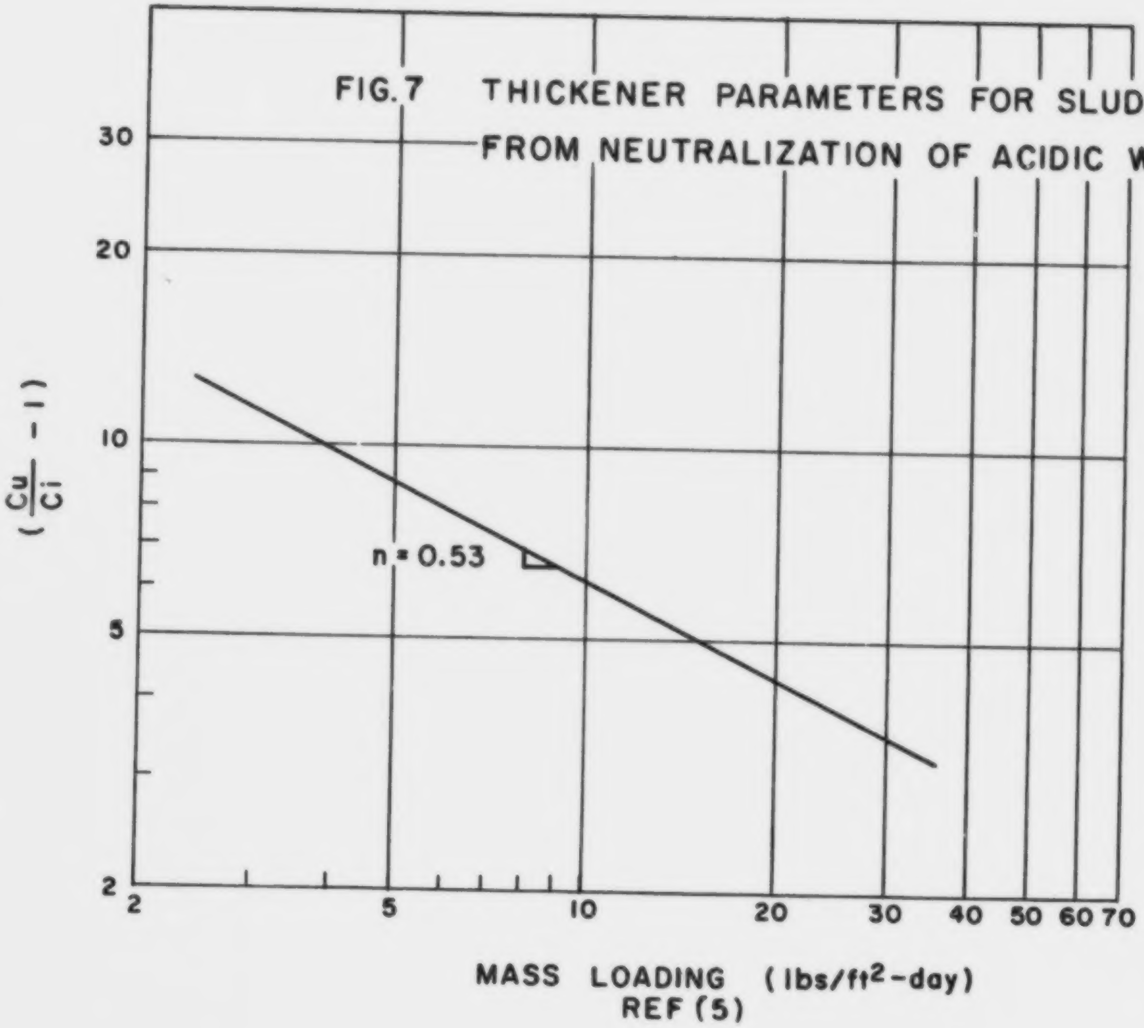

FIG. 7 THICKENER PARAMETERS FOR SLUDGE FROM NEUTRALIZATION OF ACIDIC WASTES

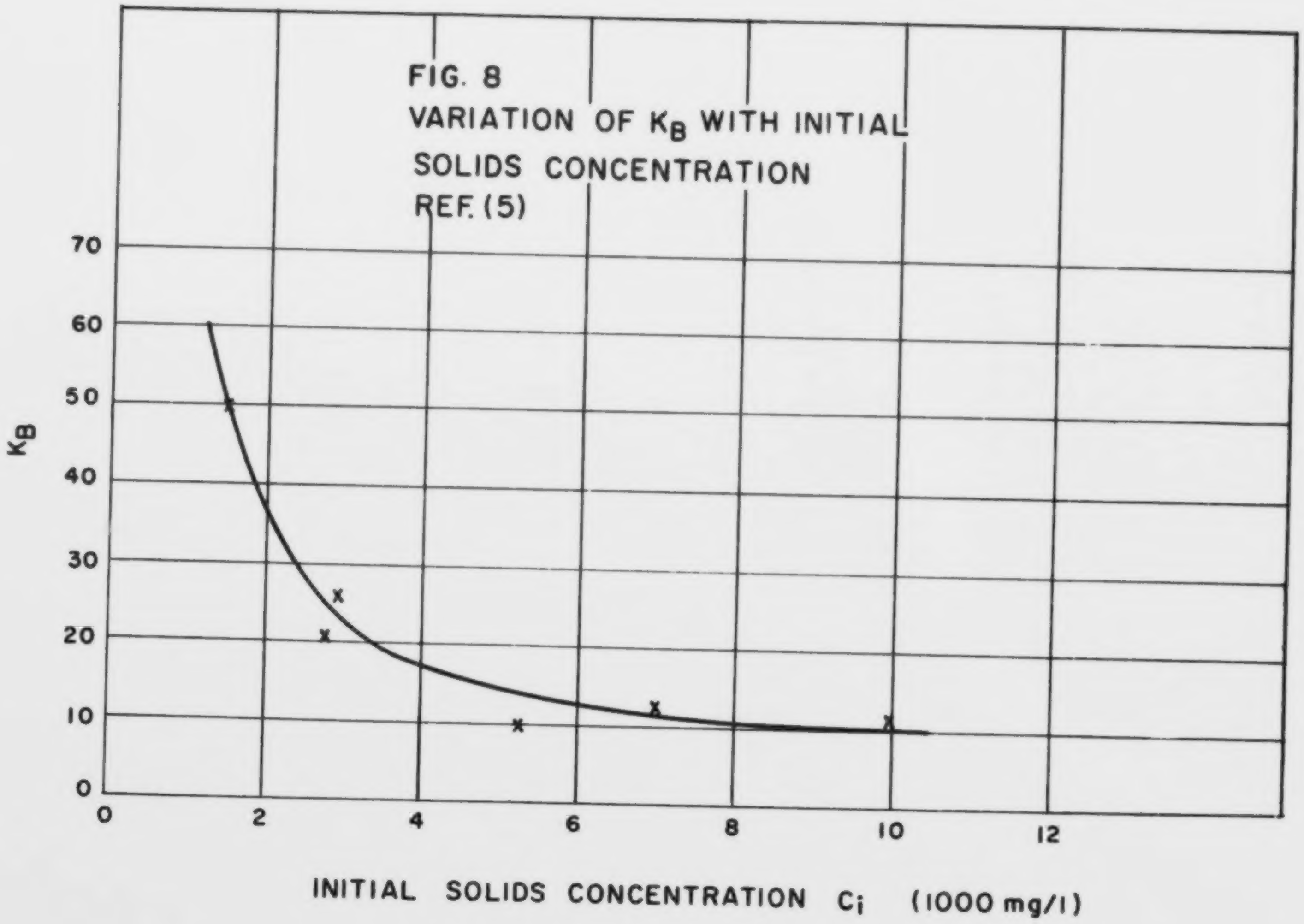

FIG. 8

VARIATION OF K_B WITH INITIAL SOLIDS CONCENTRATION REF. (5)

This model will be applied to determine the underflow solids discharged to the vacuum filter or centrifuge.

Sludge Dewatering

The cost functions used for the calculation of costs for vacuum filters and centrifuges are based on those applied by Quirck (7) for industrial wastes. The unit capacity or loading factor for vacuum filters, expressed as lb. solids per hour through one square foot $\left(\frac{\text{lbs/hr}}{\text{sq. ft.}}\right)$ will be determined from experimentally determined values (5). The cost function for centrifuges gives:

Capital Cost (\$) =
$15{,}700 \times (HP)^{0.40}$ (adjusted to ENR 1285)

The required horsepower is based on 1 HP per 1 gpm of sludge dewatered. Cost function for vacuum filters.

Capital Cost (\$) =
$4820 \times (\text{area})^{0.58}$ where the area of filter is determined by load factor.

Example of Cost Calculation for Plant Using Mechanical Dewatering

Flow rate	1.0 mgd
Acidity	2000 mg/l as $CaCO_3$
Suspended solids	200 mg/l
Precipitable metal salts	200 mg/l

The basicity of hydrated lime (2) is 0.71. For every 1 gm acidity neutralized $\frac{0.76}{0.71}$ gm of lime is used to produce 1.36 of $CaSO_4$. The basicity factor of 0.71 is probably due to some unreactive part of the lime that will end up with the sludge. Assuming that the main product of neutralization is $CaSO_4$, the concentration of the salt in the effluent will be determined by the solubility product. $(Ca^{++})(SO_4^{=}) = 10 \times 10^{-6}$, thus the molar concentration of $CaSO_4$ in solution would be 0.00315 molar or 428 mg/l. Metal precipitates will add to the sludge as will initial suspended solids. These values are normally not high. Where suspended solids are high, they will be dealt with separately under the cost function. As some metals will precipitate during neutralization, these will be added to the total acidity for the purpose of this study.

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(2) Rice, ibid

(5) Atlas Chemicals, ibid

(7) Quirck, T. P., "Application of Computerized Analysis to Comparative Costs of Sludge Dewatering by Vacuum Filter and Centrifuge," Report Quirck, Lawler and Matusky Engineers, New York.

Thus, total sludge produced given by sludge (mg/l) = 1.36 x acidity

+0.31 x acidity for unreactive lime constituents
+15% of acidity for metal ppts
-428 mg/l
=1.36 x 2000 + 0.31 x 2000 + 0.15 x 2000 - 428 =
3400 mg/l

Assume sludge production 1.7 x acidity.
Equalization for 6 hours, i.e., basin size 0.25 MG
From cost curve, Capital Cost = $20,000
Neutralization installation
From Figure 4 Capital Cost = $54,000
Thickener - clarifier
From Figure 9 Capital Cost = $110,000
Assume
Underflow solids concentration 2% solids

$$\text{Volume of sludge produced} = \frac{3400 \times 8.33}{0.02 \times 8.13} = 170{,}000 \text{ gal/day}$$

$$\text{Vacuum filter} \qquad L_f = 2.5\ \frac{\text{lbs/day}}{\text{sq. ft.}} \text{ based on Ref (7)}$$

$$\text{Filter area} = \frac{3400 \times 8.33}{2.5 \times 16}$$

$$= 710 \text{ sq. ft. for 16 hrs/day operation}$$

$$\text{Capital Cost} = \$4820 \times (710)^{0.58}$$

$$= \$216{,}000$$

Capital Cost of Centrifuge

Sludge volume = 170,000 gpd
= 142 gpm for a 20 hour day

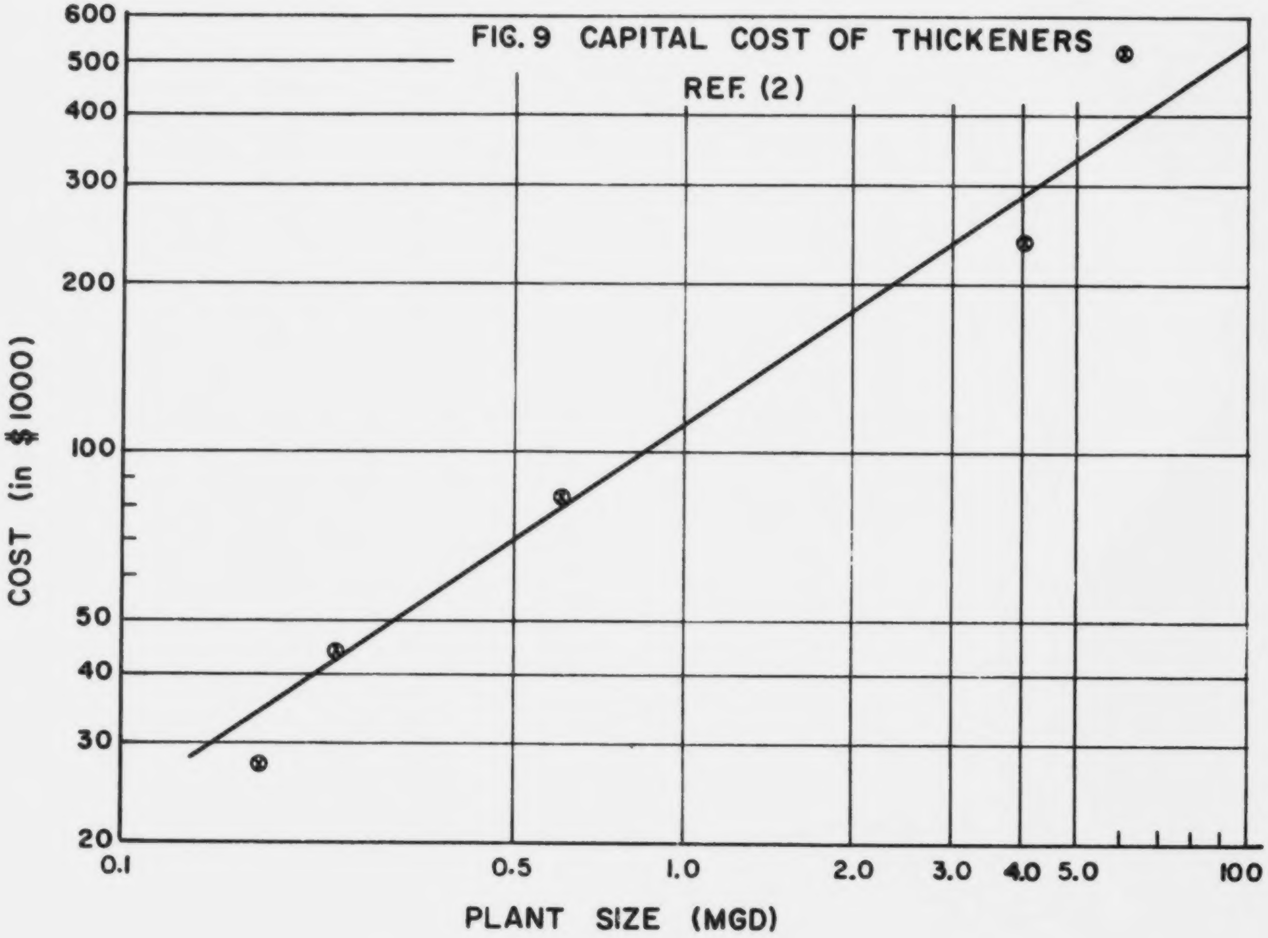

FIG. 9 CAPITAL COST OF THICKENERS

REF. (2)

which requires 142 HP

$$\text{Capital Cost} = \$15,700 \times (142)^{0.40} = \$114,000$$

The cost of the vacuum filter is much higher than for the centrifuge but there will be a substantial saving in the operating cost as little chemicals will be required to achieve the desired results. The capital cost for vacuum filtration will be used here.

Total cost (excluding trucking)

Equalization	20,000
Neutralization	54,000
Thickener clarifier	110,000
Vacuum filter	216,000
	400,000
Add 35% for site preparation pipework, etc.	140,000
	$540,000

Calculating a range of values for flow Q from 0.5 to 50 mgd and for acidity A from 500 mg/l to 10,000 mg/l, the following cost model was found:

$$\text{Capital Cost (in \$1000)} = 300 \times Q^{0.71}A^{0.34}$$

The acidity seems to be less of a factor in this model but only because trucking or other disposal of the filter cake has been included in the total calculated costs. Also, the operating cost will be much higher than for lagooning of the sludge. Although the capital costs will be lower, the total annual cost for mechanically dewatered sludge will be high.

Operating costs were determined from the acid mine drainage report without sludge disposal and the operating costs of vacuum filters were added to that. The resultant curves are shown in Figure 10.

Suspended Solids

The sludge produced from the lime neutralization process has more definite properties than the sludge produced by the settling of other suspended matter. It was assumed that at worst the suspended solids will have the same properties and for this reason, it was lumped together with acidity in the calculation of total costs.

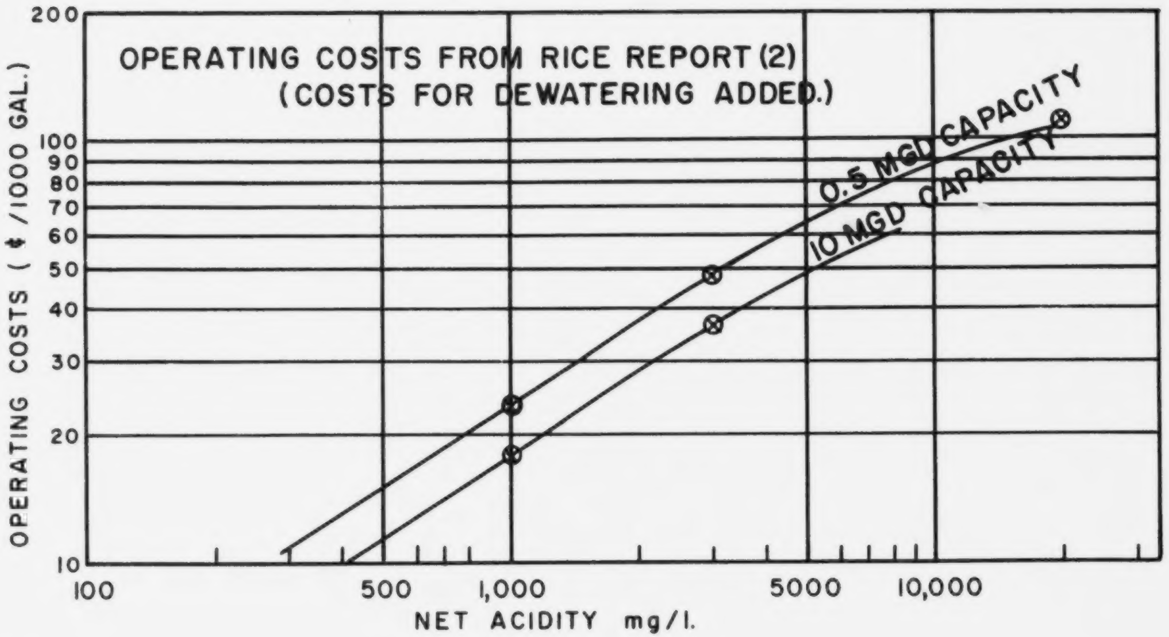

FIGURE 10
OPERATING COSTS FOR LIME NEUTRALIZATION INCLUDING SLUDGE DEWATERING BY VACUUM FILTRATION

Filtration

The cost values used for filtration were obtained from Smith's (8) curves and they are reproduced in Figure 11. The capital costs and operating costs were calculated at ENR index 1285.

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(8) Smith, R., "Cost of Conventional and Advanced Treatment of Wastewater, Journal Water Pollution Control Federation, Vol. 40, 69, September, 1968.

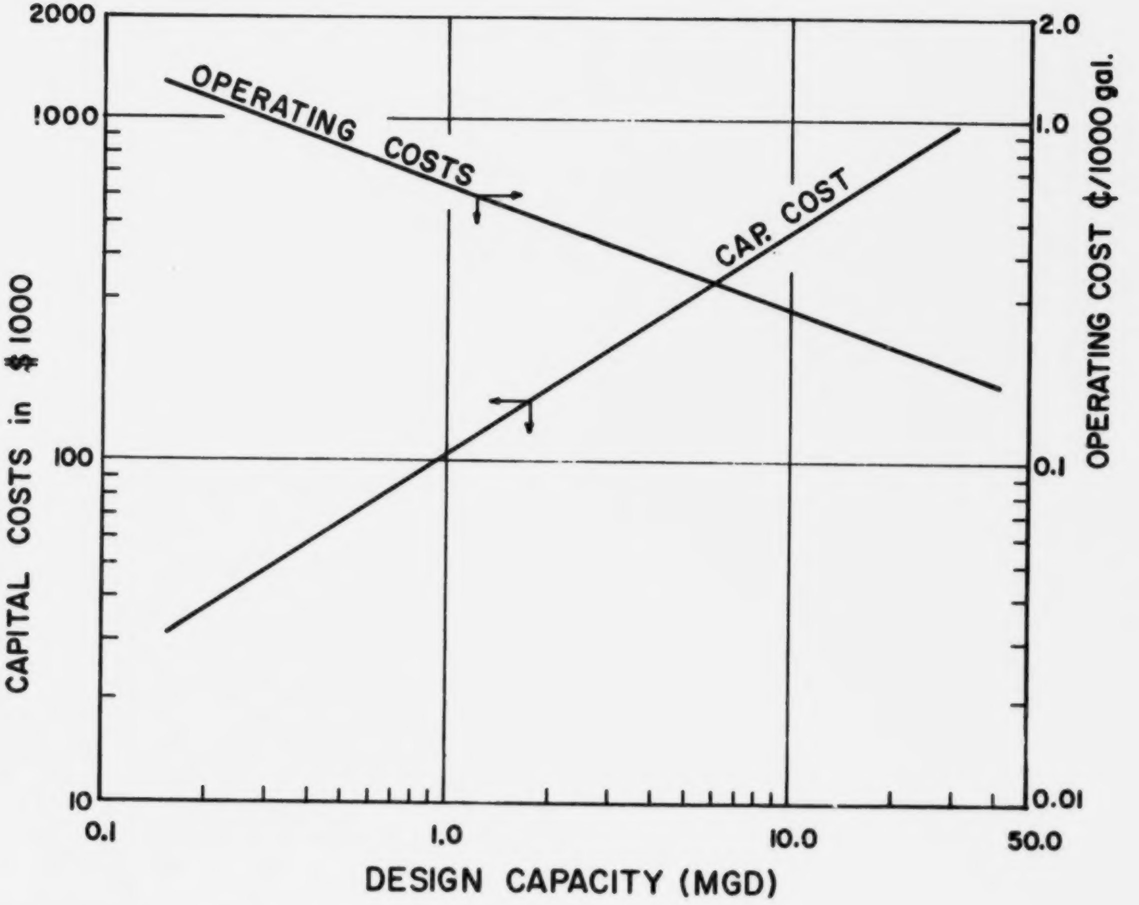

FIGURE II. COST OF FILTRATION THROUGH SAND OR GRADED MEDIA AFTER SMITH (8)

DEEP WELL DISPOSAL

The capital cost and operating cost for deep well injection systems are presented in the attached Figures 12 and 13. These costs are presented for different flow rates as well as casing head pressures. The capital costs are expressed in terms of total capital investment and the operating cost is expressed on an annual basis. In order to develop usable curves, it is necessary to select typical geological and hydraulic systems (9). Therefore, the following items were constant:

Depth
Effective Thickness
Porosity
Permeability
Reservoir Pressure of the Disposal Horizon

The diameter of the injection stream was also held constant and for this particular example was seven inches. The geological characteristics assumed were based on evaluation of existing data and are valued to represent the conditions at more than 50 percent of the existing installations. The operating costs are based on a power cost of 0.005 dollars per kilowatt hour, an interest rate of five percent and a payout period of 20 years.

The ENR building cost index of 700 was used for estimating the capital cost. These cost flows include minimal service treatment. If service treatment greater than filtration is required, the cost of the additional unit process must be added to the capital and operating cost shown in Figures 12 and 13.

In order to convert costs to 1969 values with ENR index 1285, the values from the curve were multiplied by 1.84.

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(9) Moseley, J. C., and J. F. Malina, Jr., "Relationships Between Selected Physical Parameters and Cost Responses for the Deep-Well Disposal of Aqueous Industrial Wastes," Report published by the Center for Research in Water Resources, Technical Report, EHE-07-6801, CRWR-28, The University of Texas at Austin, (August, 1968).

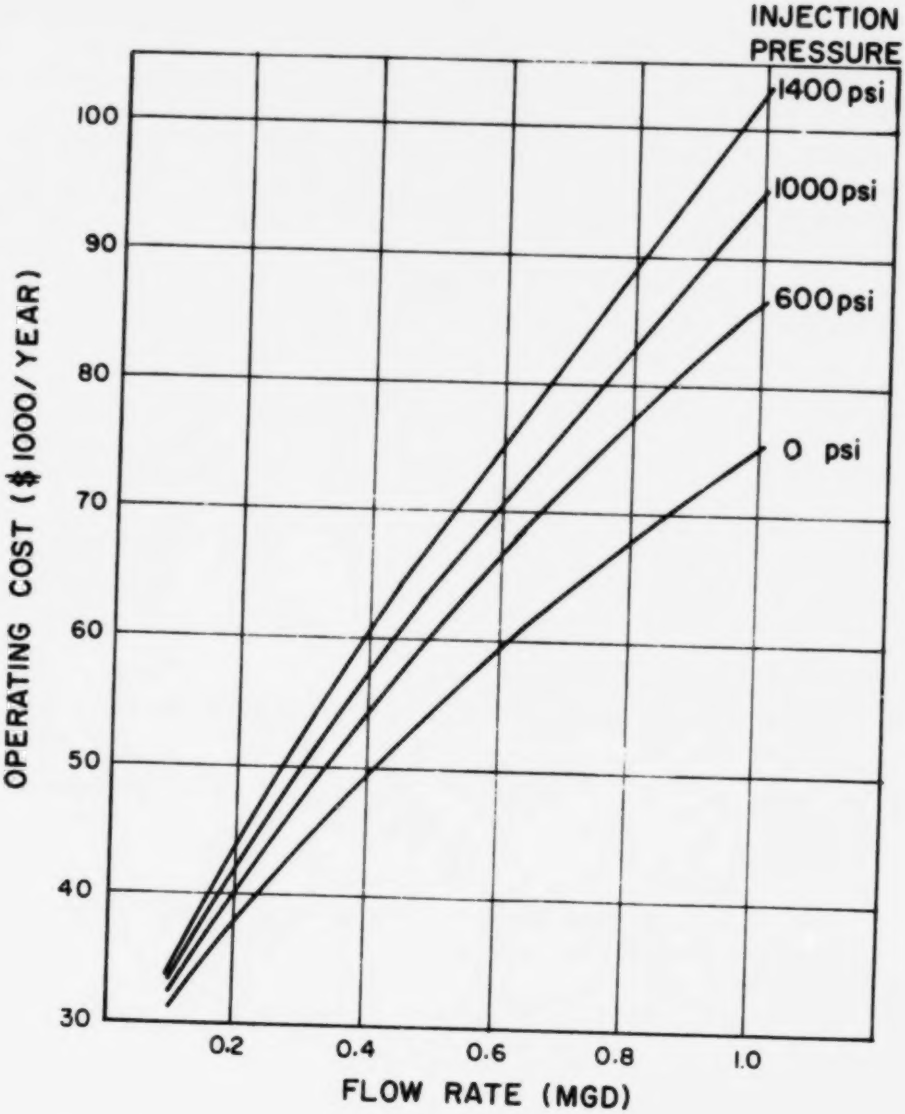

FIG. 12

ANNUAL OPERATING COST OF DEEP WELL INJECTION SYSTEMS FOR WASTE DISPOSAL

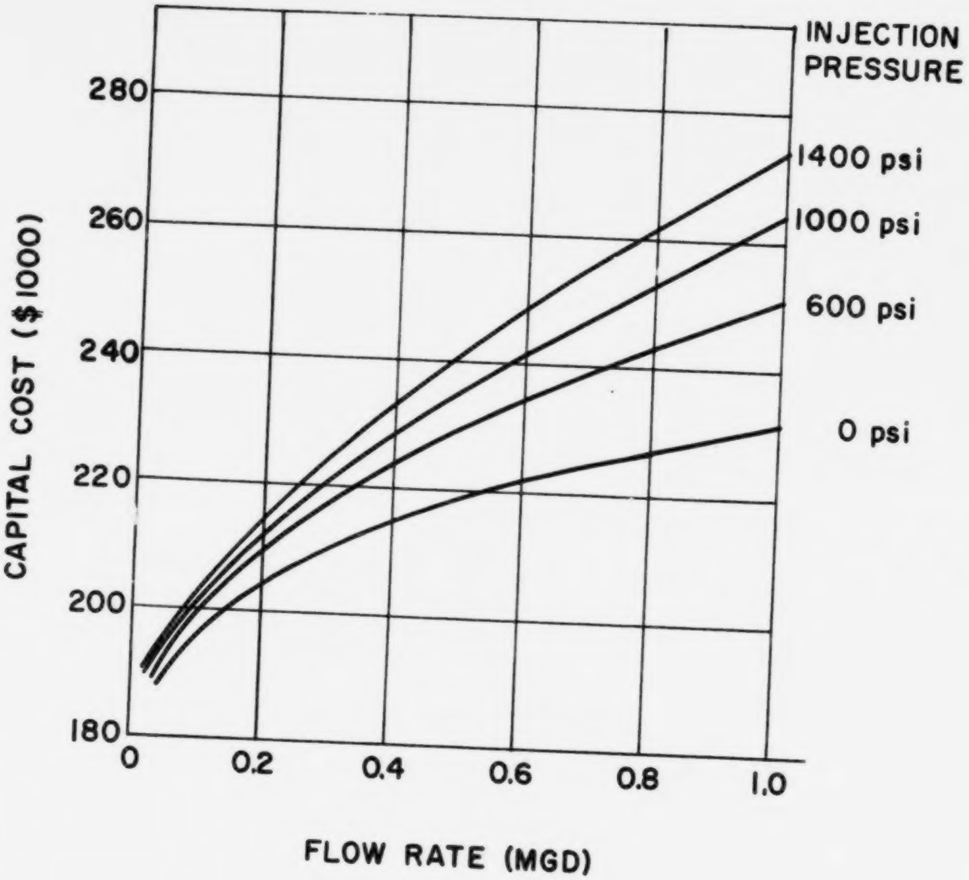

FIGURE 13
CAPITAL COST OF DEEP WELL INJECTION SYSTEMS FOR WASTE DISPOSAL

REVERSE OSMOSIS

The curves actually used for cost calculation were obtained from the Acid Mine Drainage Report (2) and they are reproduced in Figures 14-17. The pretreatment and brine disposal required was considered separately. These curves gave generalized cost figures. If more accurate assessments are required, one can calculate the yield and the actual membrane size required. This is demonstrated below. For a high total dissolved solids content, it is necessary to make an assumption as to the number of units required to produce the desired effluent. Also, the feasibility of rejection of brine at certain levels should be considered. From the viewpoint of producing palatable water only, one may reject a large quantity of brine for every unit of water produced if brine disposal presents no problem. However, when brine disposal does present a problem, the amount produced must be minimized. For disposal for treatment purposes, both the value of the water produced and the cost of brine disposal will determine the degree to which the concentration of the brine must be increased or, conversely, the total volume of the brine decreased.

The curves (Figures 14-16) were plotted from actual data of pilot and demonstration plants. The membrane area required depends on many factors including: membrane characteristics (salt rejection, porosity, etc.), applied pressure, water characteristics, and the feed flow.

The capital costs quoted here are for the entire plant including installation. However, the operating costs are for power consumption only. Membrane replacement costs have been estimated at $0.35/1000 gal. of product flow. The estimated overall projected figure would be .35 + .98 = $1.33/1000 gal of treated water (10). This is a very conservative estimate and does not consider future improvements in membrane technology.

The operating costs do not include pretreatment to remove undesirable pollutants such as iron, manganese, organics, etc., and do not consider ultimate disposal of the brine.

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(2) Rice, ibid

(10) Spiegler, K. S., Principles of Desalination, Academic Press, (1966).

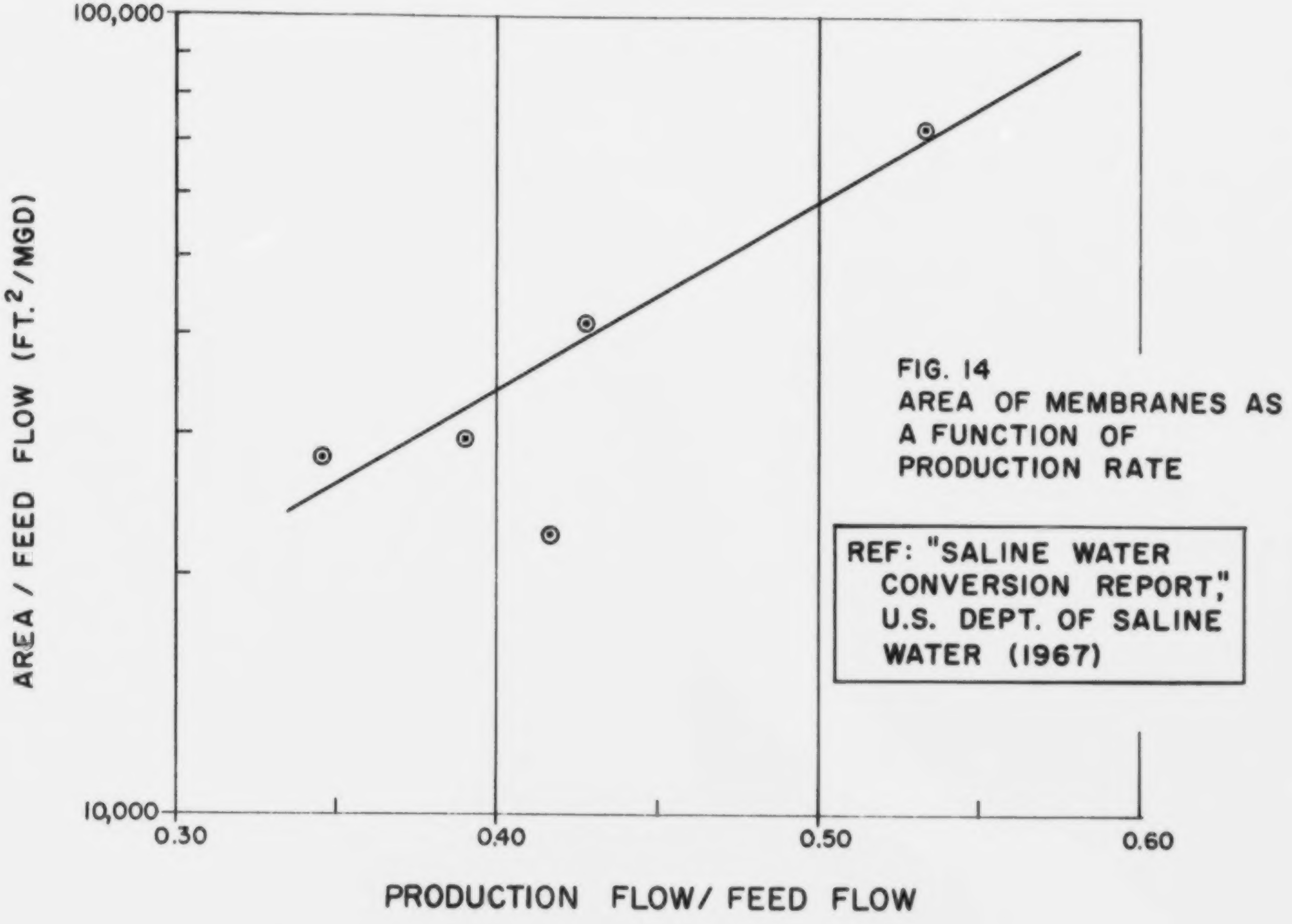
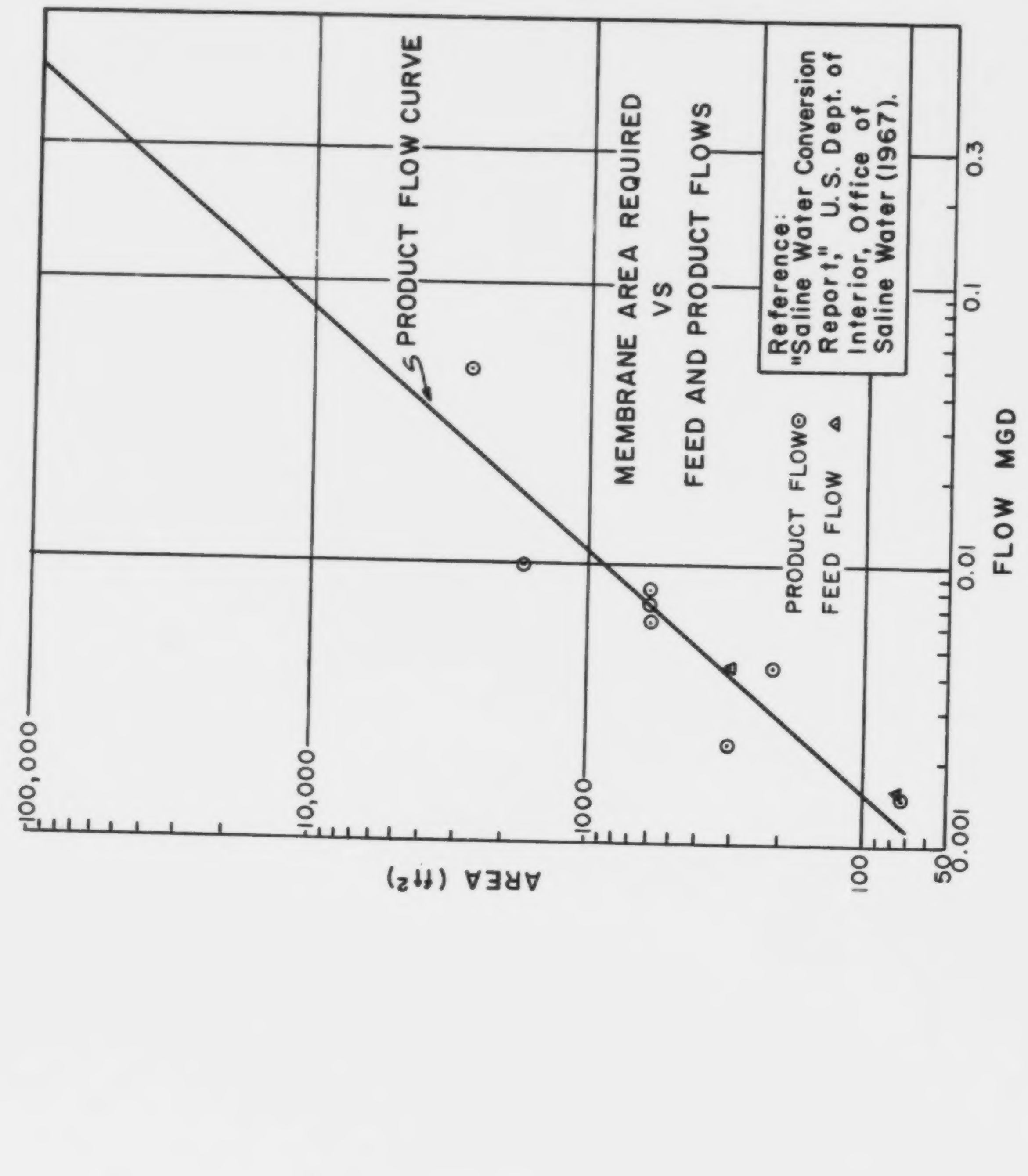


FIG. 14
AREA OF MEMBRANES AS
A FUNCTION OF
PRODUCTION RATE

REF: "SALINE WATER CONVERSION REPORT," U.S. DEPT. OF SALINE WATER (1967)

FIGURE 15



Reference:
"Saline Water Conversion Report," U.S. Dept. of Interior, Office of Saline Water (1967).

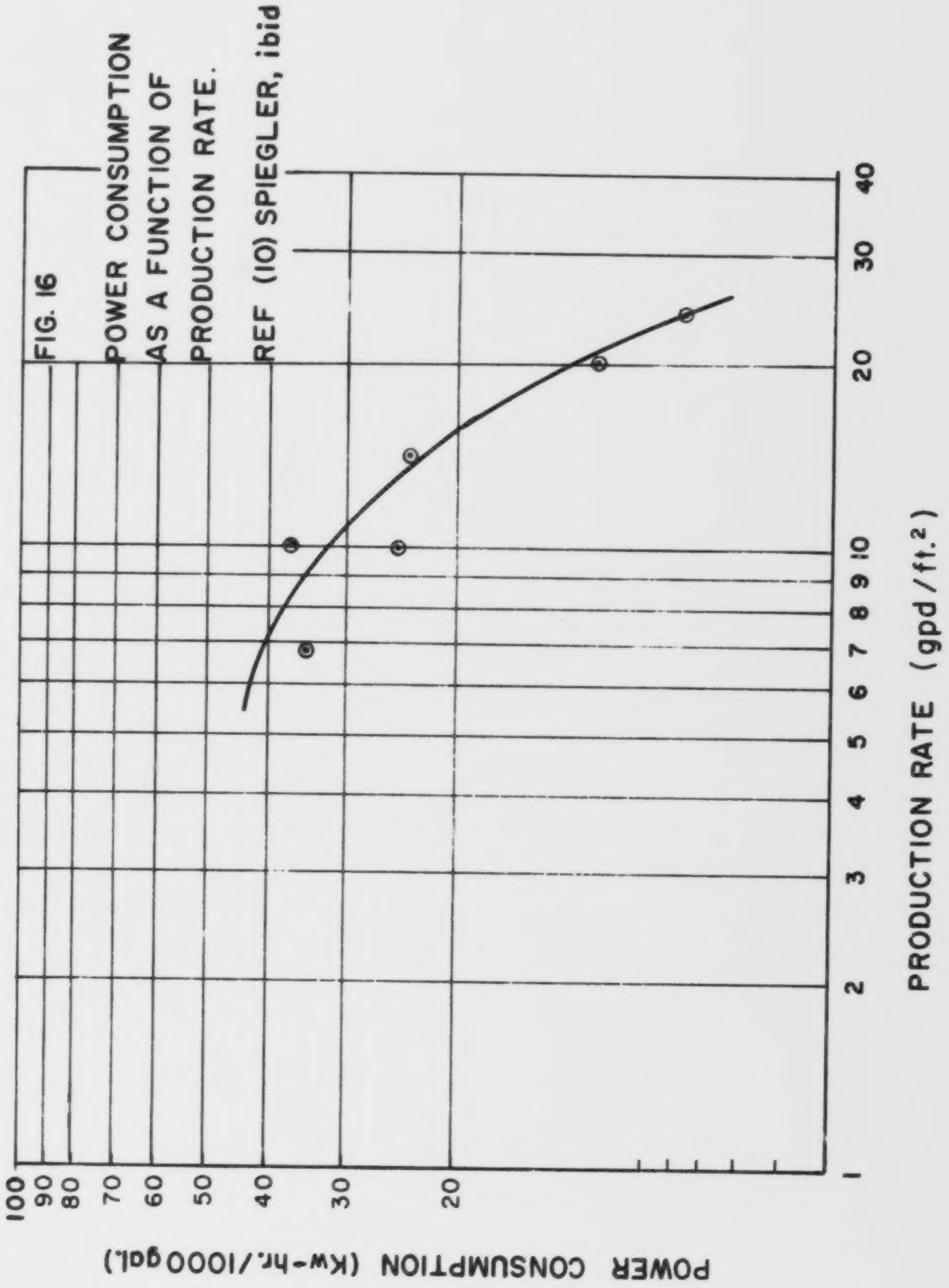
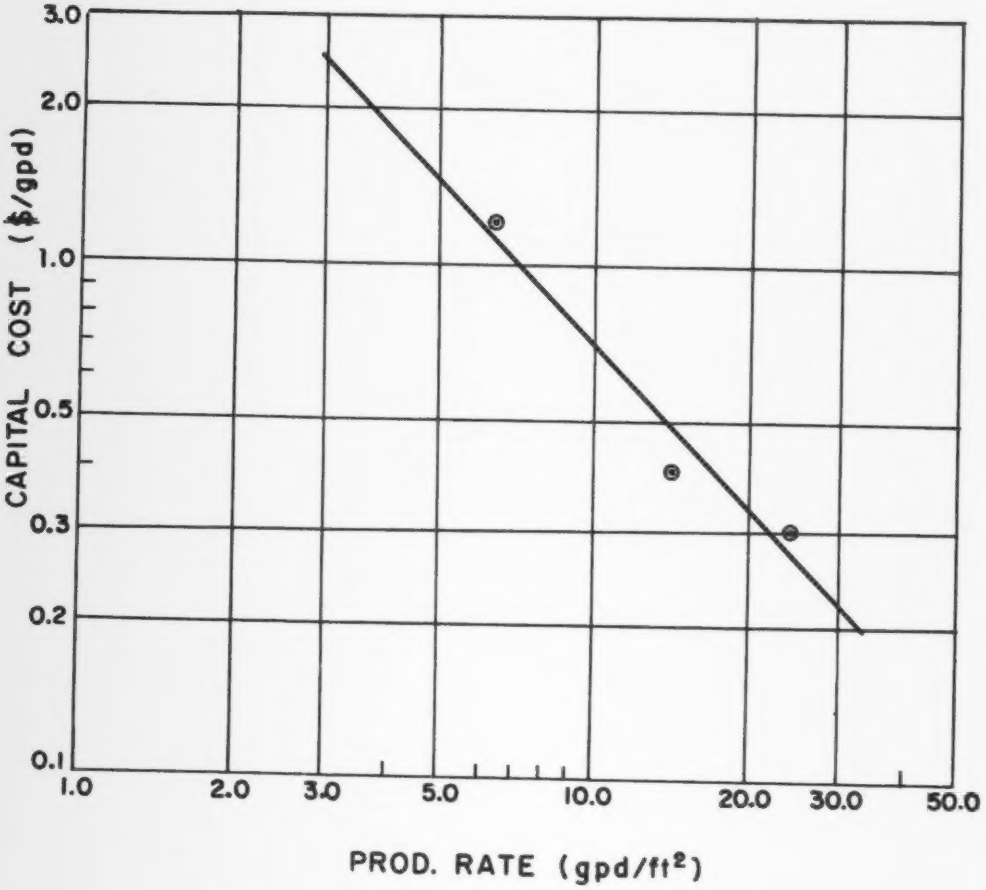


FIG. 16

POWER CONSUMPTION AS A FUNCTION OF PRODUCTION RATE.

REF (10) SPIEGLER, ibid

FIG. 17
CAPITAL COST AS A FUNCTION OF PRODUCTION RATE
REF. (10) SPIEGLER, ibid



The latter was considered separately for calculating the cost of treatment.

Most work with reverse osmosis has been concerned with TDS levels of 1000-5000 mg/l. Thus, the plots presented are based on these ranges. Higher levels of TDS would probably require much more specific surface for equivalent removals, thus increasing capital expenditures. Also, maintenance costs would be increased due to increased scaling, etc.

I. REQUIRED DATA: Plant Flow, Removal Desired Production Flow (amount of plant flow to be recovered through membrane)

If plant flow = 1 mgd and a recovery factor of 60% is desired, then the production flow = 600,000 gpd = 0.60 mgd waste flow = 0.40 mgd

At influent concentration of 5000 mg/l TDS and a desired effluent of 500 mg/l, the desired removal or fractional "cut" would be 0.90.

II. SIZE OF PLANT AND POWER CONSUMPTION

Product flow = 0.60 mgd
Prod/Feed = 0.60
From Figure 14: Area/Feed flow = 102,000 ft^2/mgd
$\therefore$ Total Area = 102,000 ft^2
check: From Figure 15: @ Prod. Flow = 600,000 gpd,
Area = 102,000 ft^2
Production rate = 600,000/100,000 = 6.0 gpd/ft^2
From Figure 16: Power = 44 KW-hr/k gal = 44,000 KW - hr/day

III. COSTS

Capital Cost

Production rate = 5.0 gpd/ft^2
$\therefore$From Figure 17:
Capital Cost = 1.20 \$/gpd + 10^6 gpd

Operating Cost

Power Consumption = 44,000 kw-hr/day (Figure 16)
$\therefore$@ \$0.015/kw-hr
Power Cost = \$660/day

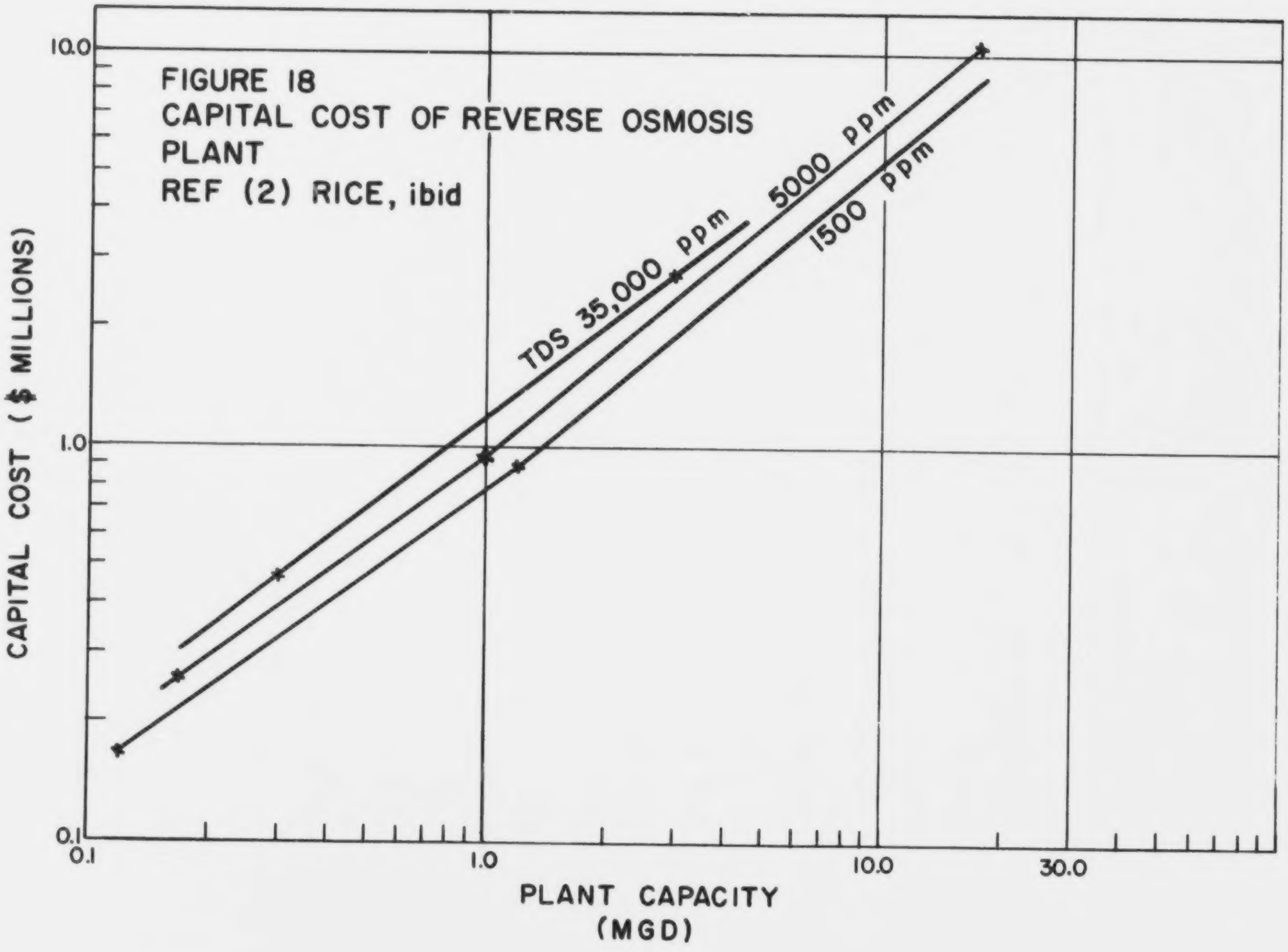


FIGURE 18
CAPITAL COST OF REVERSE OSMOSIS
PLANT
REF (2) RICE, ibid

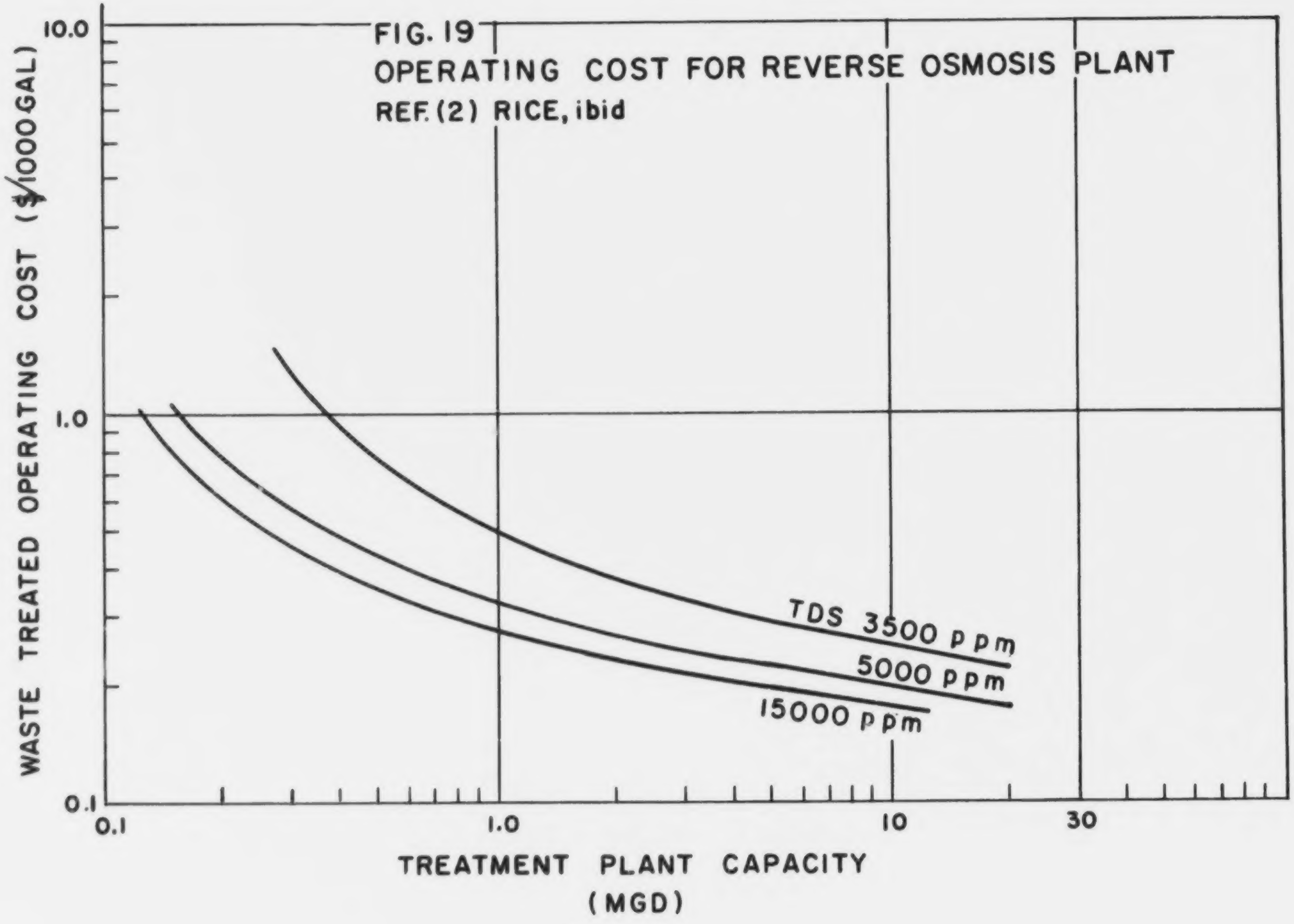


FIG. 19
OPERATING COST FOR REVERSE OSMOSIS PLANT
REF. (2) RICE, ibid

ELECTRODIALYSIS

Cost figures for electrodialysis were difficult to obtain because this method is mostly used where brine disposal does not represent a problem or very high concentrations of effluent brine or not necessarily required. As a treatment method to concentrate and thus reduce the volume of brine produced, a slightly increased number of cells will have to be used and a proper balance between brine produced and usable water production will depend on the need or cost of the clean water as well as the cost of brine removal. To get some idea of the number of units required to concentrate waste streams and produce a product effluent of less than 500 mg/l total dissolved solids, a study was made of existing data (11) to produce the set of curves in Figure 20. This will give some idea of the number of units required and the relative amounts of effluent and brine produced. With recirculation of the waste through the cells the concentration in each cell will reach an equilibrium value which is not easy to calculate. Certain values were assumed and the units calculated according to this. Using basic design parameters, the size of the plant was calculated for waste with varying values of total dissolved solids. These values were then used for calculating the final capital costs. From Figure 22, the volume of brine was calculated and the cost of disposal of the brine was added to the cost of treatment.

Design Equations

$$\text{I.} \quad nAp = \frac{1000\ Fd\ F(2K_2C_{d_i}f + K_1Z)}{CE\ (i/Cd)_o(2K_2C_{d_i}\ (1-f) + K_1{}^Y)}$$

nAp = effective transfer area, cm^2 (n=number of individual cell pairs)

f = fraction of total cut through filter (the TDS removal factor) (measure of approach to polarization and film diffusion limitations) should stay less than 0.5

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(11) Electrodialysis in Advanced Waste Treatment, FWPCA Publ. No. WP-20-AWTR-8. Water Pollution Control Research Service (1967).

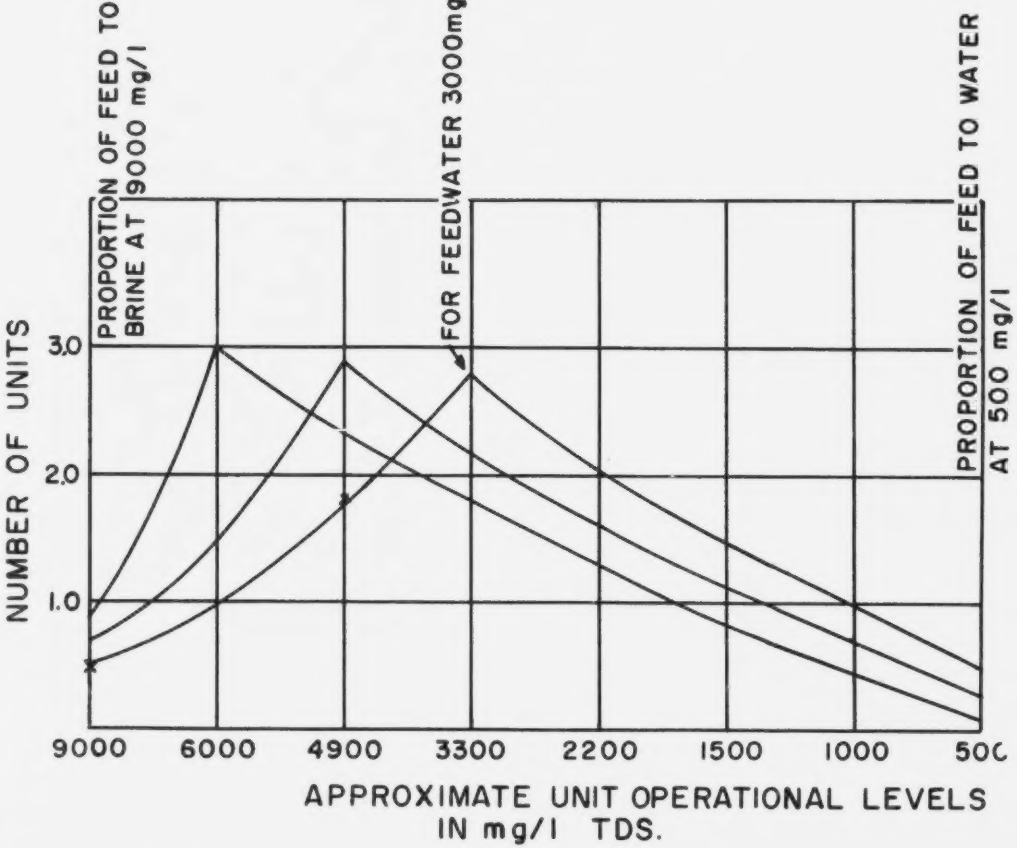


FIGURE 20
DETERMINATION OF TOTAL NUMBER OF UNITS REQUIRED FOR TREATMENT

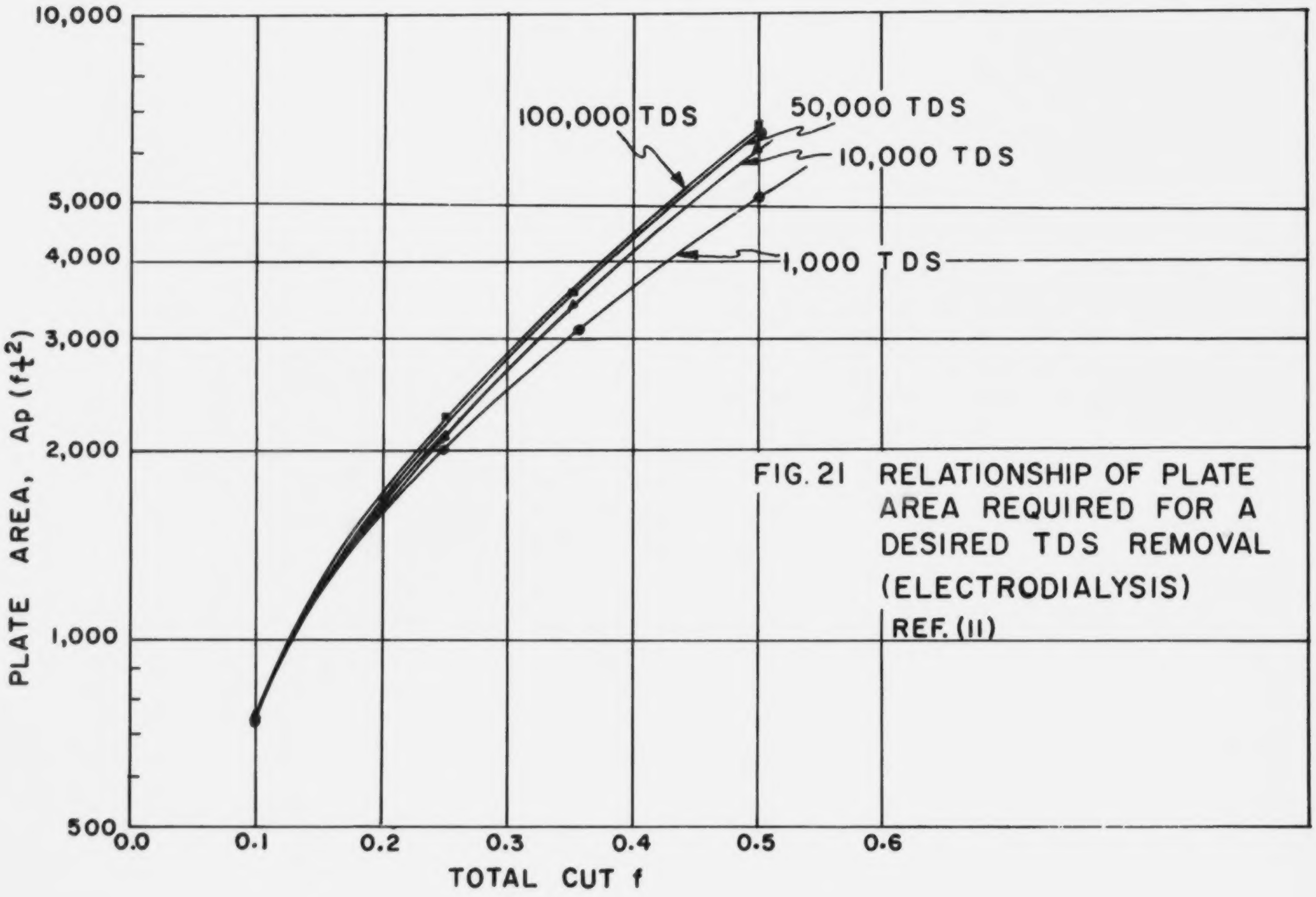


FIG. 21 RELATIONSHIP OF PLATE AREA REQUIRED FOR A DESIRED TDS REMOVAL (ELECTRODIALYSIS)
REF. (11)

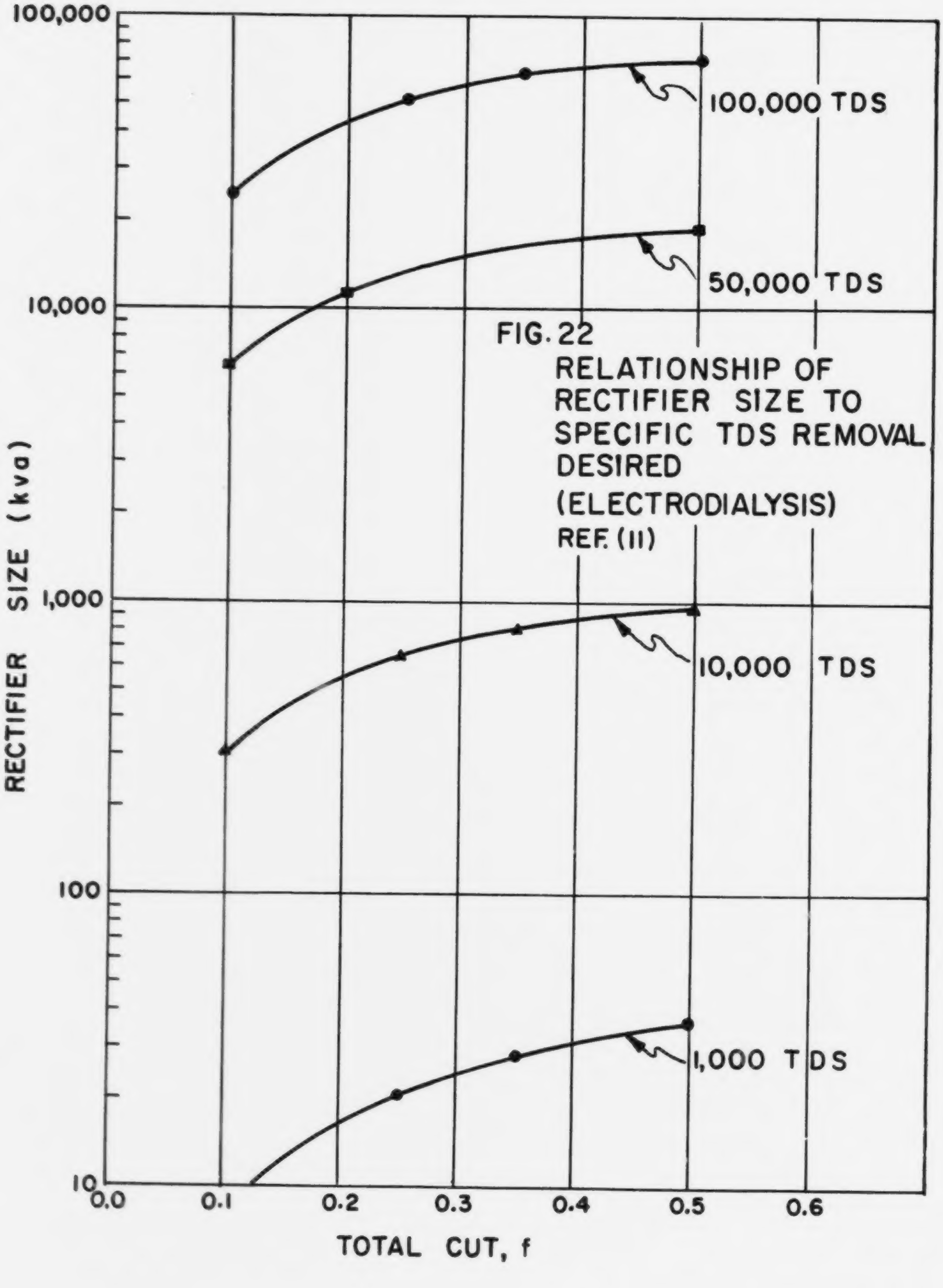


FIG. 22
RELATIONSHIP OF RECTIFIER SIZE TO SPECIFIC TDS REMOVAL DESIRED
(ELECTRODIALYSIS)
REF. (11)

$= (C_{d_i} = C_{d_e})/Cdi$

F = Faraday's constant, 96,500 coulombs/equivalent

i = current density, ma/cm^2

F_d = influent dilute stream flow rate, liters/sec

Cd_i = influent dilute stream concentration, equivalent/liter

Cci = concentrated stream concentration equivalent/liter

k_1, k_2 = constants depending on various membranes, solutions, and temperature parameters
k_1/ca = a solution resistance term
k_2 = a membrane resistance term

$Y = 1 + \frac{(1-f)g}{(gf+1)}$ $(i/Cd)_o$ = a measure of approach polarization. Thus, there is an upper limit to this ratio.

$Z = \ln \frac{(1+gf)}{(1-gf)}$

$g = C_{d_i}/C_{c_i}$

CE = current efficiency

II. $V_p = \frac{(i/Cd)o}{1000} \left(\frac{K1}{2} (Y + K2\ (1-f)\ Cdi)\right)$

V_p = potential drop across membranes, volts

$I = \frac{Fd\ F\ f\ Cdi}{nCE}$

DC power requirement = $P = (V_p I)$ in kva

TABLE I

SUMMARY

Influent TDS	f	Plate Area (ft^2)	DC Energy (kw-hr)	ED Unit Cost $	Rectifier Cost	Operating Cost DC Energy Cost $/MGD
1,000	0.50	5,180	988	45,380	2,500	9.88
	.35	3,110	742	27,160	1,875	7.42
	.25	2,038	553	17,830	1,400	5.53
	.10	731	235	6,400	595	2.35
10,000	0.50	6,120	26,200	53,600	66,100	262
	.35	3,440	21,600	30,140	54,600	216
	.25	2,177	17,800	19,040	45,000	178
	.10	742	8,220	6,480	20,800	82
50,000	0.50	6,560	494,000	57,450	1,250,000	4,940
	.20	1,678	307,000	14,690	776,000	3,070
	.10	745	171,000	6,503	431,000	1,710
100,000	0.50	6,640	1,890,000	58,150	4,770,000	18,900
	.35	3,585	1,710,000	31,410	4,330,000	17,100
	.25	2,270	1,450,000	19,860	3,550,000	14,050
	.10	747	649,000	6,531	1,641,000	6,490

Example: 10 mgd plant
TDS = 1000 mg/l
Normality = 0.01 equiv./liter

Allowable effluent concentration = 600 mg/l

.˙. f = 1000 - 600/1000 = 0.40

Capital Considerations

From Figure 21: Area of plates
= 3,700 ft^2/mgd + 10 mgd
= 37,000 ft^2 total

From Figure 22: Rectifier size
= 30.25 ku-a/mgd + 10 = 302.5 ku-a

From Figure 23: Capital cost of plates, spacers, membranes and electrodes
= 31.500/mgd
= $315.000 total

From Figure 24: Capital cost of rectifier
= $2100/mgd + 10 mgd
= $21,000 total

Capital Cost = $315,000 + $21,000 =	$336,000
Stack hardware = $500/mgd =	5,000
10% installation = 0.10 (341,000) =	3,410
Auxiliary equip. (installed @ 40%) pumps, valves and fittings, control panels, acid tanks, conduct = 20.000/mgd = (10% miscellaneous included)	200,000
Total 1/	$544,400

1/ exclusive of building, spare parts, etc.

Operating Conditions

From Figure 25: DC Energy Requirements
= 840 kw-hrs/mgd
= 8400 kw-hrs

FIGURE 23
CAPITAL COST OF MEMBRANES, SPACERS, END PLATES, AND ELECTRODES (ELECTRODIALYSIS) REF. (11)

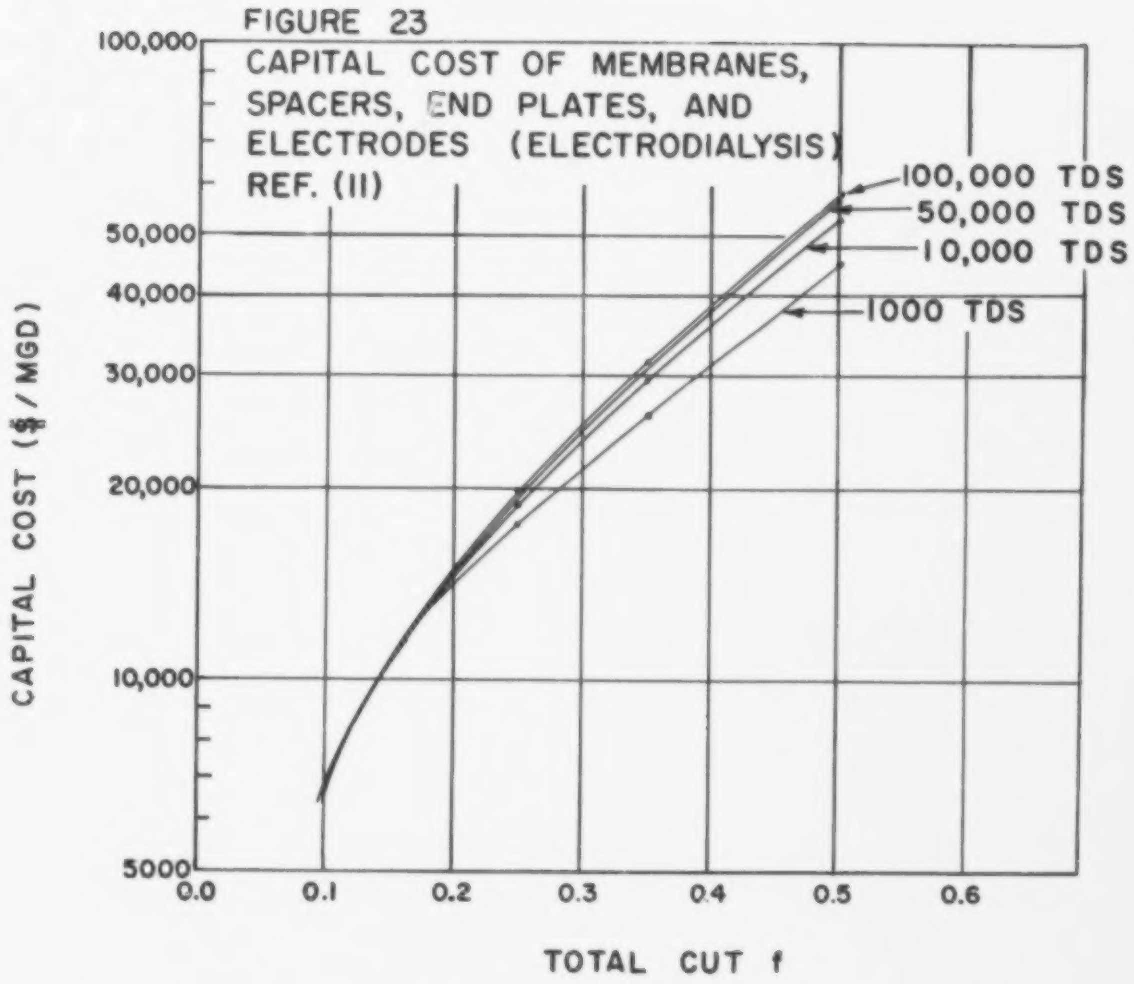
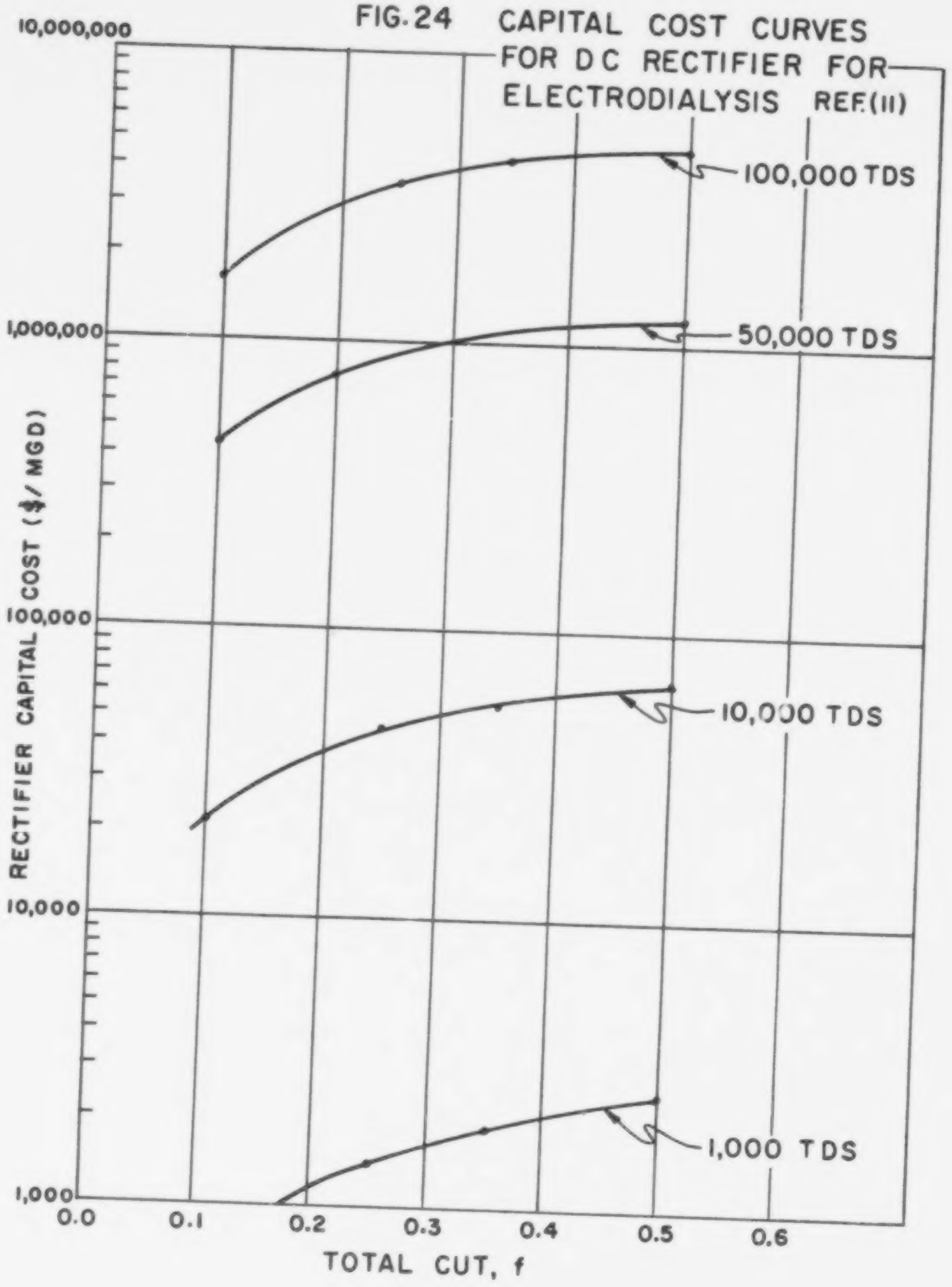


FIG. 24 CAPITAL COST CURVES FOR DC RECTIFIER FOR ELECTRODIALYSIS REF.(II)



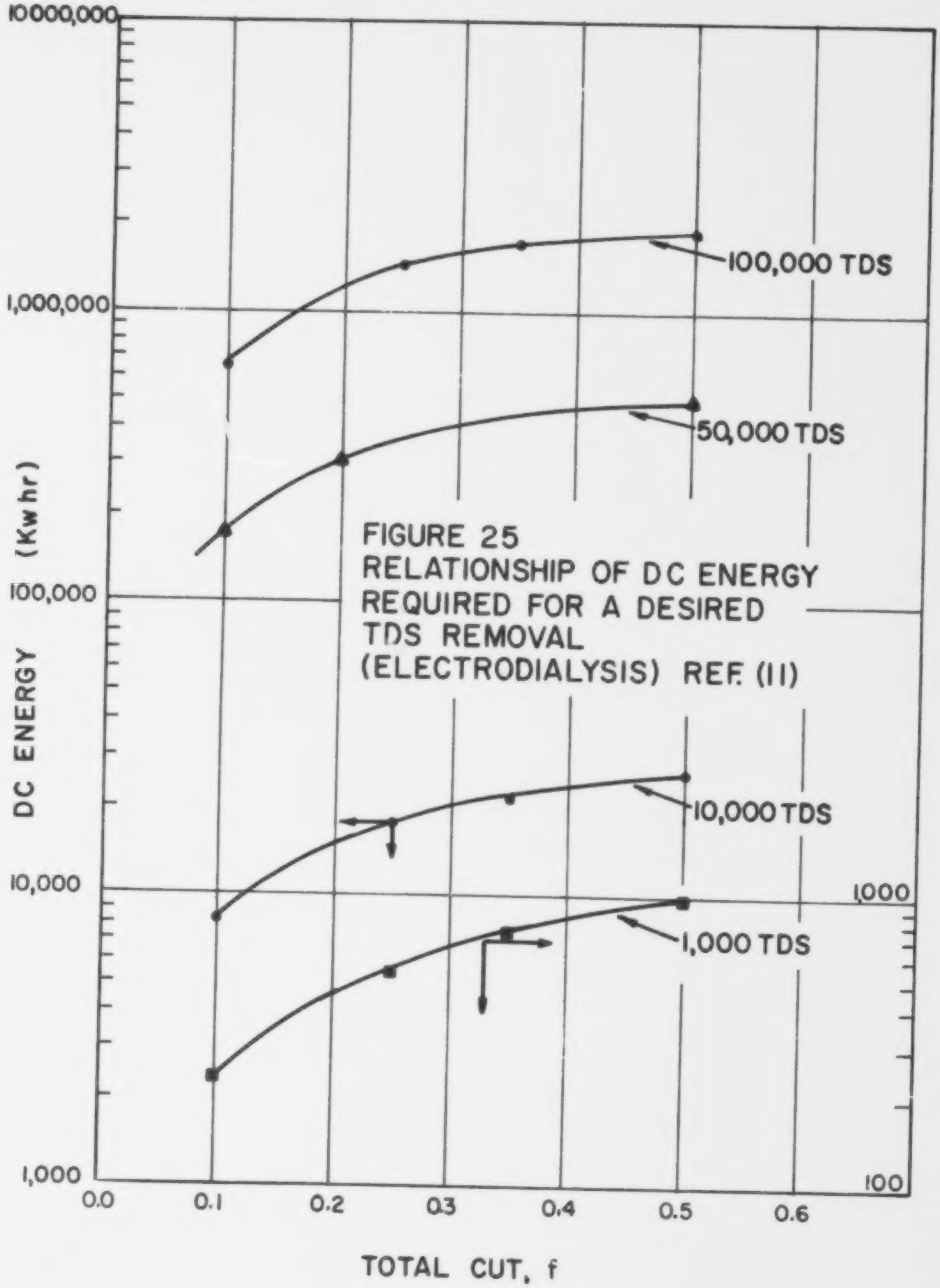


FIGURE 25
RELATIONSHIP OF DC ENERGY
REQUIRED FOR A DESIRED
TDS REMOVAL
(ELECTRODIALYSIS) REF. (11)

From Figure 26: DC Energy Operating Costs @ \$0.01/kw-hrs
= 8.40/mgd
Total 1/ = \$8.40/day

Costs for 0.5 mgd wastewater at 3000 mg/l total dissolved solids.

From Figure 20, the following units would be required to deliver equal volumes of product water at 500 mg/l total dissolved solids and brine at 10,000 mg/l.

Approximate Feed Concentration	# Units/ mgd	Cost/ Unit	Total Cost
3,000	2.8	58,000	81,000
2,200	2.0	52,000	52,000
1,500	1.4	50,000	35,000
1,000	0.7	47,000	16,000
4,900	1.8	70,000	63,000
6,000	1.0	78,000	78,000
			325,000
			81,000
		Plus 25% for pumps	406,000

These costs were obtained from costs calculated from the fundamental design equations. Similar costs evaluated for other points and those were plotted on Figure 27.

Values for operating costs were calculated as shown in the Appendix and the values also are shown in Figure 27. One value obtained from Ref. (12) is shown to be within the calculated range of operating costs.

1/ Must include maintenance costs:
Membrane replacement = 4 sets/25 years
Spacer replacement = 4 sets/25 years
Anode maintenance - \$200/stack year
Other maintenance = 1-1/2% of capital investment/year
Labor = 2 man-hrs./day plus 100 man-hrs. per stack year
Other operating costs would be acid or alkali additions to maintain a suitable pH.

(12) Lacey, R. E., Lang, E. W., and Huffman, E. L., "Economics of Demineralization by Electrodialysis," Saline Water Concession II. Advances in Chemistry Series 38. American Chemical Society, 1155 16th St., N.W., Washington, D.C., 1963.

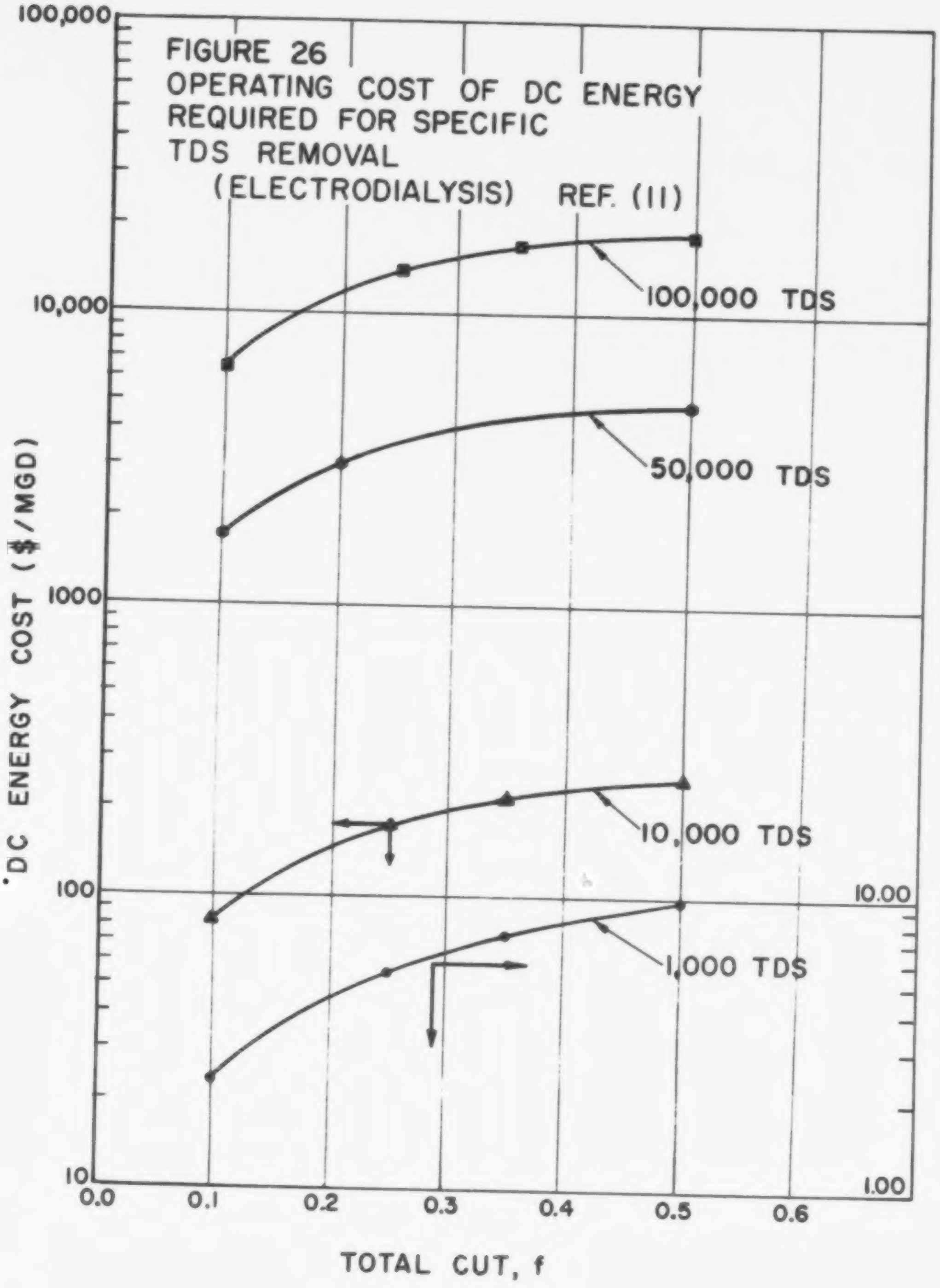
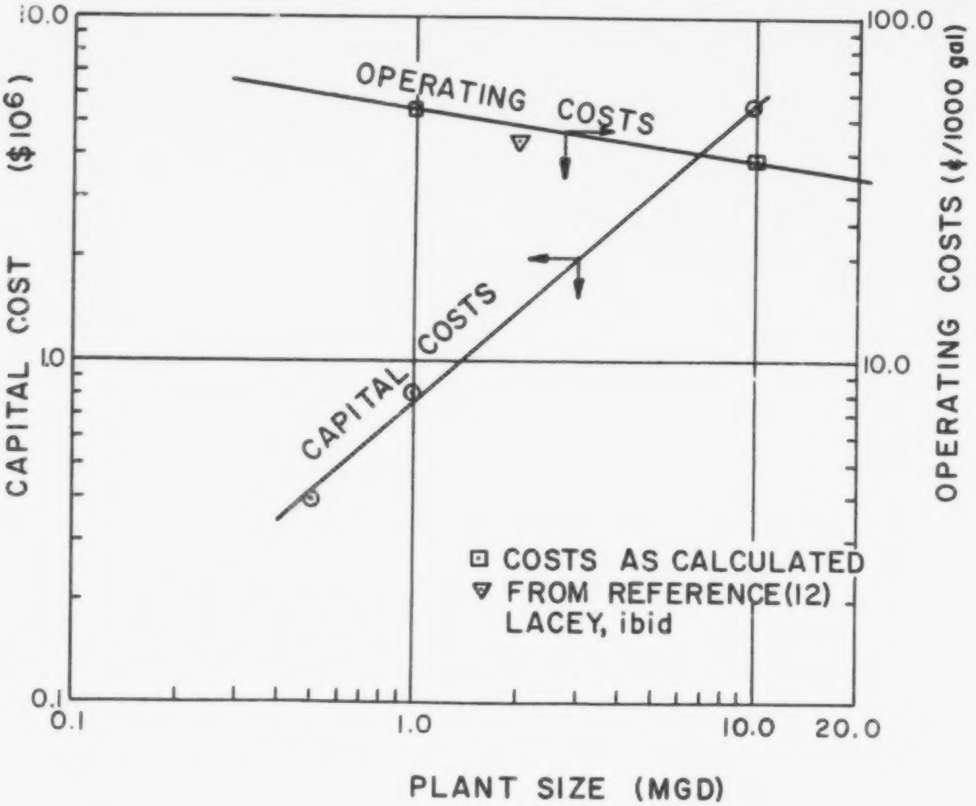


FIGURE 26
OPERATING COST OF DC ENERGY REQUIRED FOR SPECIFIC TDS REMOVAL (ELECTRODIALYSIS) REF. (11)

FIGURE 27
CAPITAL AND OPERATING COSTS FOR ELECTRODIALYSIS BASED ON FEED FLOW TO PLANT AT 3000 ppm T. D. S.



ION EXCHANGE

The cost of ion exchange plants is dependent on the total volume of waste treated but also to a large extent on the total amount of dissolved solids removed or exchanged since the flow rate through the media remains fairly constant. The regenerant chemical cost will also be in direct proportion to the rate of electrolyte removal. The water used for the wash cycle may for the purpose of treatment, be returned to the filter and recycled and will thus be added to the waste stream. The waste stream will be very concentrated and provide a possibility of recovery of chemicals if such chemicals have any commercial values.

The cost curves in Figure 28 were obtained from the Acid Mine Drainage Report (2) for the Nalco process for an influent TDS of 1500 mg/l. The curve for the Desal Process was obtained from Kunin, et al (13).

The No. 3 curve in Figure 28 was calculated on the basis of the increased capacity required for the increased ion concentration in the waste.

Operating costs for ion exchange were obtained from various sources and pieced together to give a reasonable estimate of the total operating costs. Costs for chemicals used per lb. of TDS removed varies with the initial concentration of the solids in the influent. The curve in Figure 29 was drawn from the following information:

Influent TDS (mg/l)	Chemical Cost per Pound TDS Removed
200	10.2 Ref (14)
354	4.05 Ref (14)
1000	2.0 Ref (15)

---

(2) Rice, ibid

(13) Kunin, R., et al "Desal Process-Economic Exchange System for Treating Brackish and Acid Mine Drainage Waters and Waste Effluents," Chemical Engineering Progress Symposium Series No. 90, Vol. 64, AICHE, 1968.

(14) Levendusky, et al "An Innovation in Ion Exchange," Industrial Water Engineering, Vol. 2, 11, Nov., 1965.

(15) Lyons, D., M.S. Thesis, University of Texas at Austin, 1969.

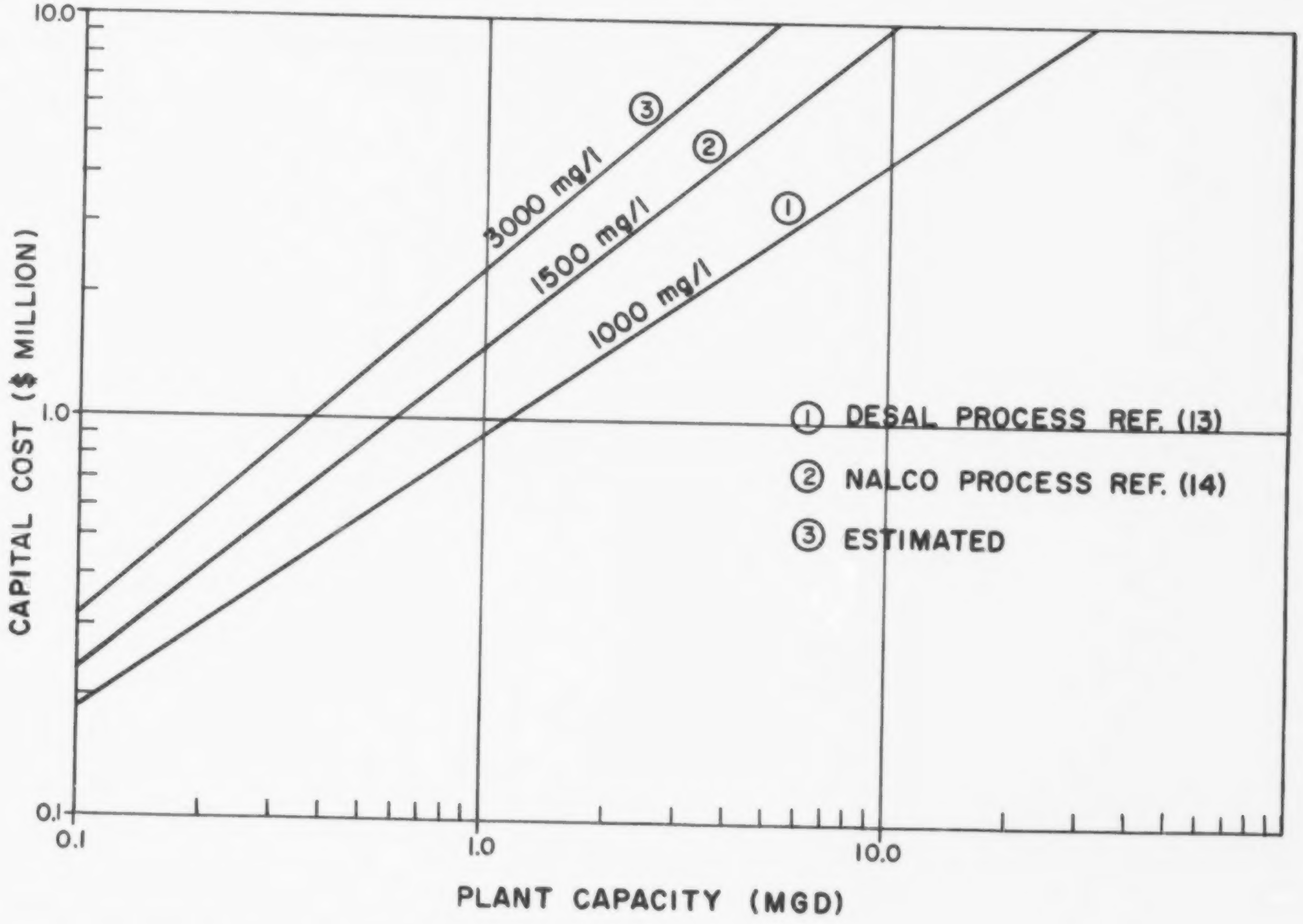


FIGURE 28 CAPITAL COST OF ION EXCHANGE PLANT

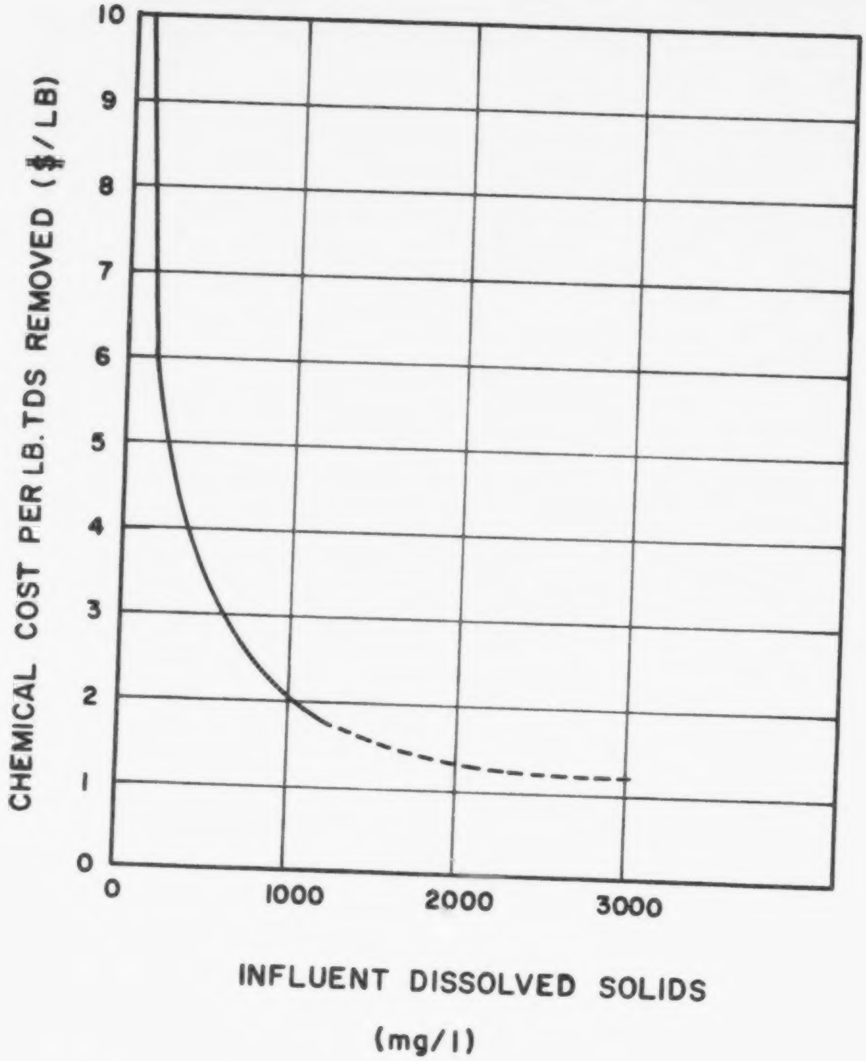


FIG. 29 CHEMICAL COST PER POUND TDS REMOVED BY ION EXCHANGE

The total operating cost for an influent TDS of 3000 mg/l was calculated as follows:

For 0.5 mgd - 2500 mg/l removed for effluent concentration of 500 mg/l

Chemical Costs:
0.001 x 1.5 x 2500 x 8.33 = 31.2¢/1000 gal.

Other Costs:

Labor	1.1
Material	1.4
Chemicals	31.2
Utilities	1.3
	35.0 ¢/1000 gal.

For 1.0 mgd

Labor	0.9
Material	1.2
Chemicals	30.0
Utilities	1.2
	33.3 ¢/1000 gal.

For 10.0 mgd

Labor	0.7
Material	0.9
Chemicals	27.0
Utilities	1.0
	29.6 ¢/1000 gal.

MULTIPLE EFFECT EVAPORATION

The capital and operating costs for multiple effect evaporation was obtained from the report "Cost of Purifying Municipal Wastewater by Distillation." Environmental Health Series, Report No. AWTR-6, U.S. Department of HEW (1963). The costs were based on product water and from the above report, it appears that approximately 10% brine is produced. Few operating costs were available. Additional points were obtained from a report in the 1965 report "Saline Water Conversion Report," U.S. Department of the Interior, Office of Saline Water.

The capital and operating costs are shown in Figure 30.

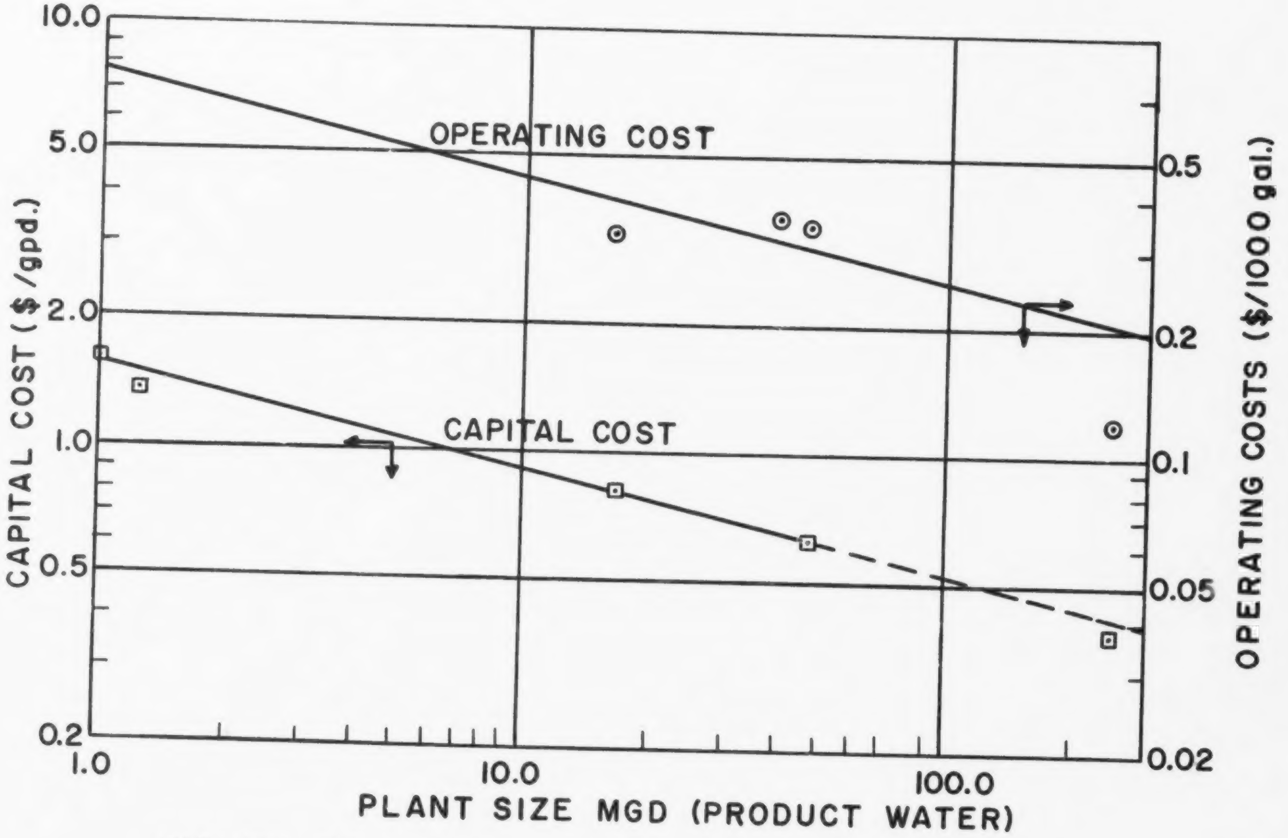


FIGURE 30
CAPITAL AND OPERATING COST FOR MULTIPLE EFFECT EVAPORATION (DISTILLATION)

SOLAR EVAPORATION

Pond evaporation would only be considered in areas where the land is cheap and the net evaporation exceeds the net rainfall by a sufficient margin so as to keep the evaporation ponds within reasonable limits. An example of such a calculation is given below. No areas of pond required are calculated and land value is assumed to be a minimal $100/acre. The costs for construction of the ponds shown in the curve in Figure 34 does not include the cost of land.

Example:
Industry located in Austin, Texas
Discharge -0.1 mgd high solids. T° @ 140°F

METHOD 1 - Average conditions (long term) (Empirical approach)

Determine annual precip. from U.S. Weather Bureau data - 32"

Determine annual lake evaporation from U.S. Weather Bureau = 60"

Net evaporation - 60-32 = 28"/yr or .0735"/day

From Figure 33 enter @ evaporation/day = .074

Read chart @ acres/mgd = 520

Average required = .1 x 520 = 52 acre

(values are 50% occurrence values).

METHOD II - short term conditions - (Rational Approach)

(1) from local weather bureau, or compiled data (17) Determine (95% occurrence value)

---

(16) The Nation's Water Resources, USGPO, Washington, D.C., 1968, Part 1.

(17) Evaluated Weather Data for Cooling Equipment, Flow Products Company, Santa Rosa, Calif. (1958)

COX CHART

REF (18) HIMELBLAU, ibid

VAPOR PRESSURE OF WATER VS TEMPERATURE

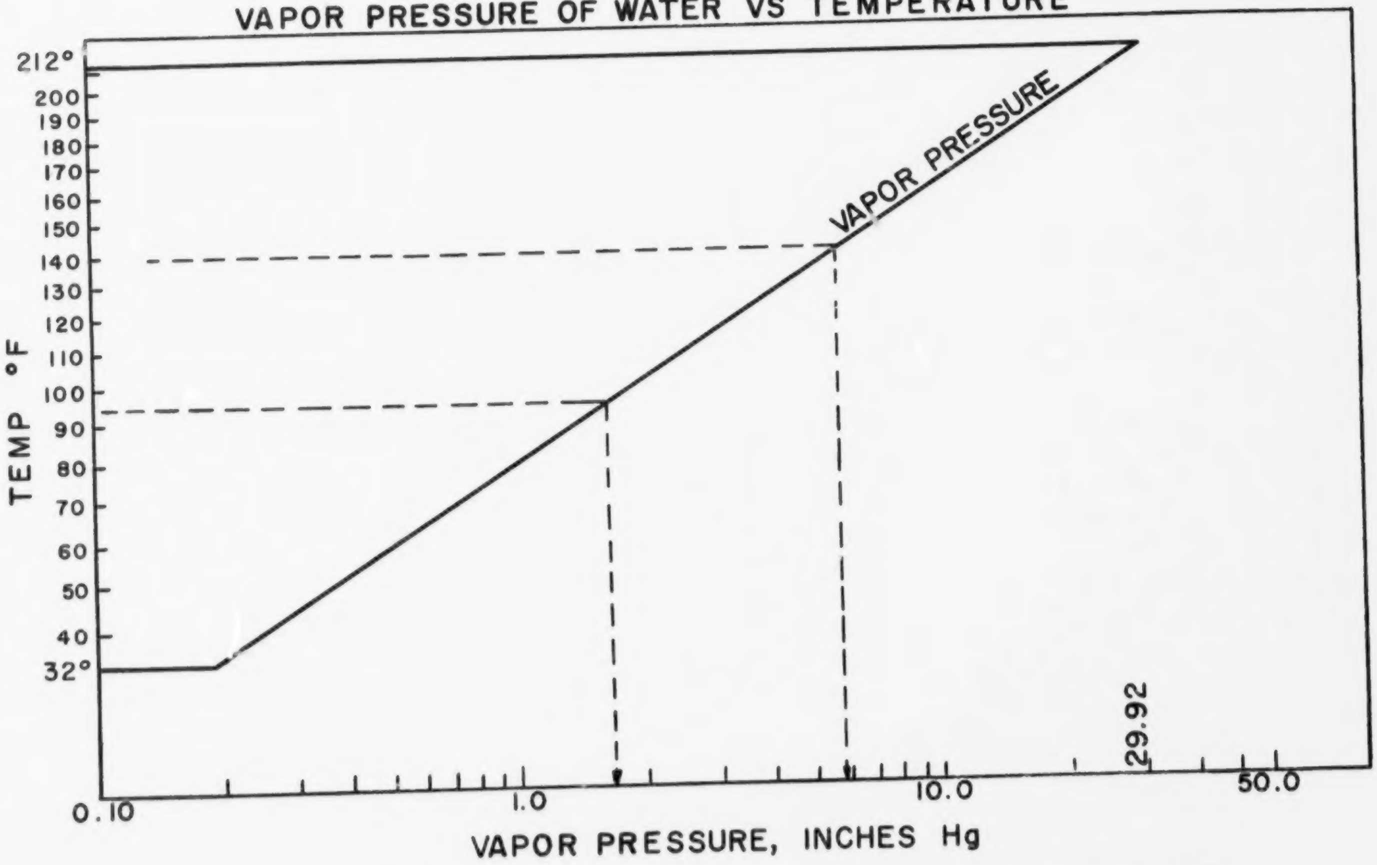


FIGURE 31

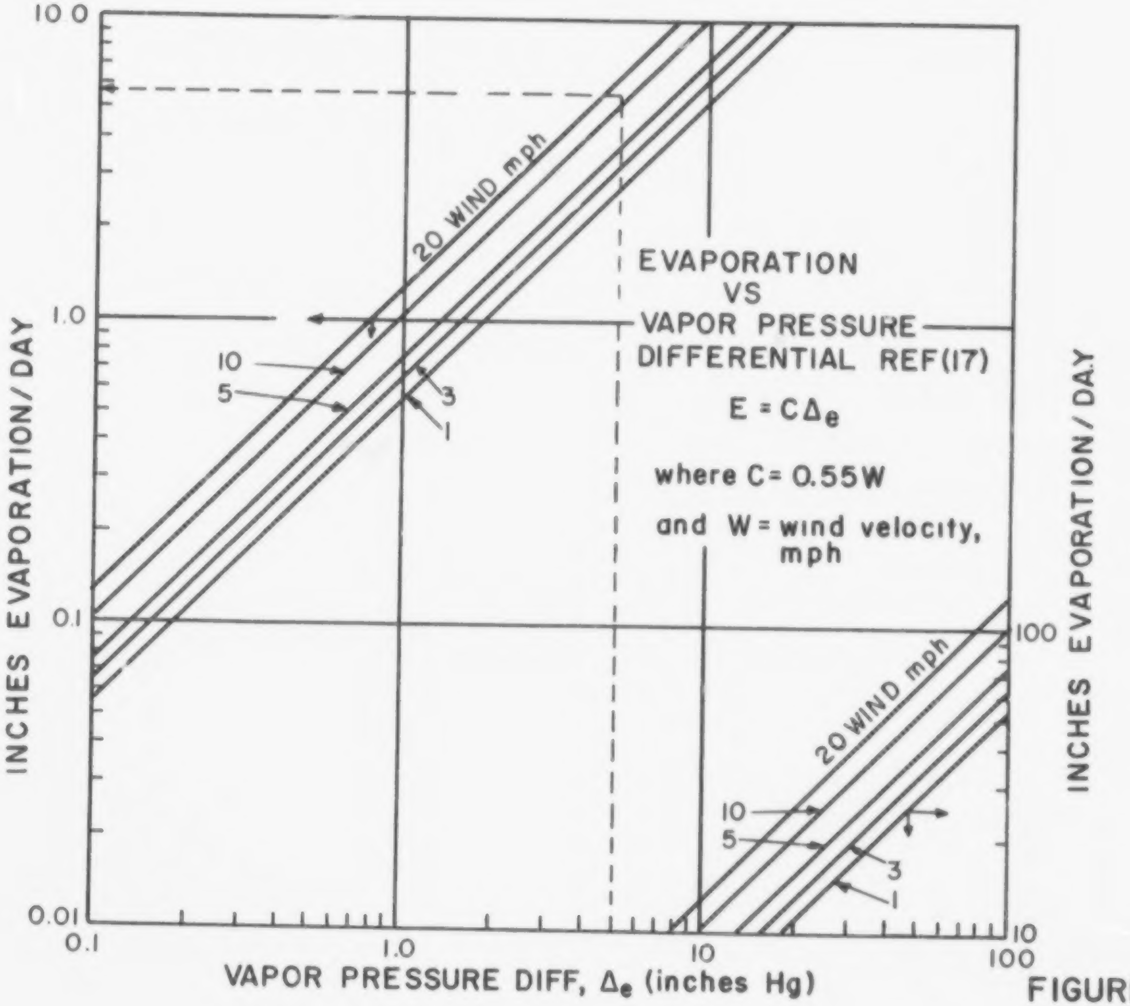

EVAPORATION
VS
VAPOR PRESSURE
DIFFERENTIAL REF(17)
$E = C\Delta_e$
where C= 0.55W
and W = wind velocity, mph
20 WIND mph
10
5
3
1
20 WIND mph
10
5
3
1
INCHES EVAPORATION/DAY
10.0
1.0
0.1
0.01
INCHES EVAPORATION/DAY
100
10
0.1
1.0
10
100
VAPOR PRESSURE DIFF, Δ_e (inches Hg)

FIGURE 32

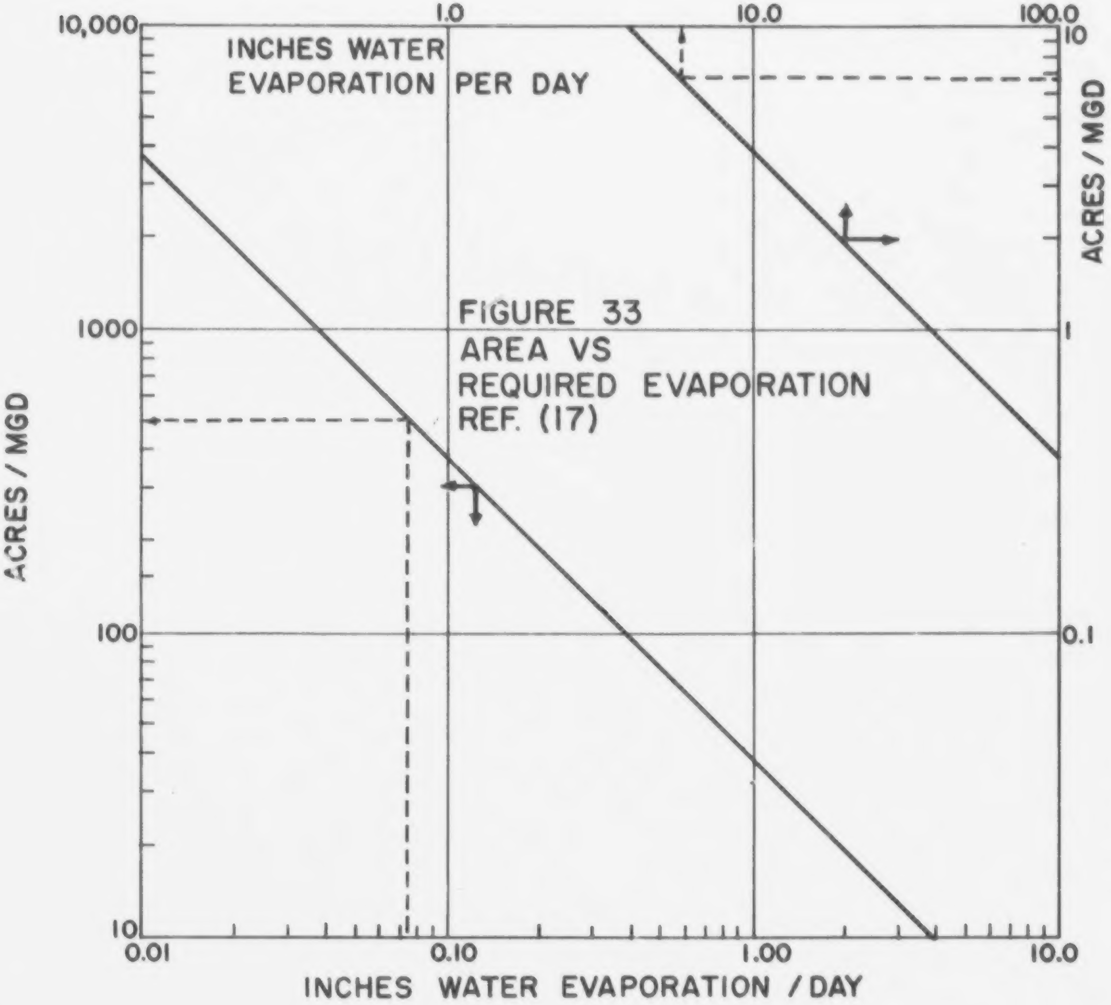


FIGURE 33
AREA VS
REQUIRED EVAPORATION
REF. (17)

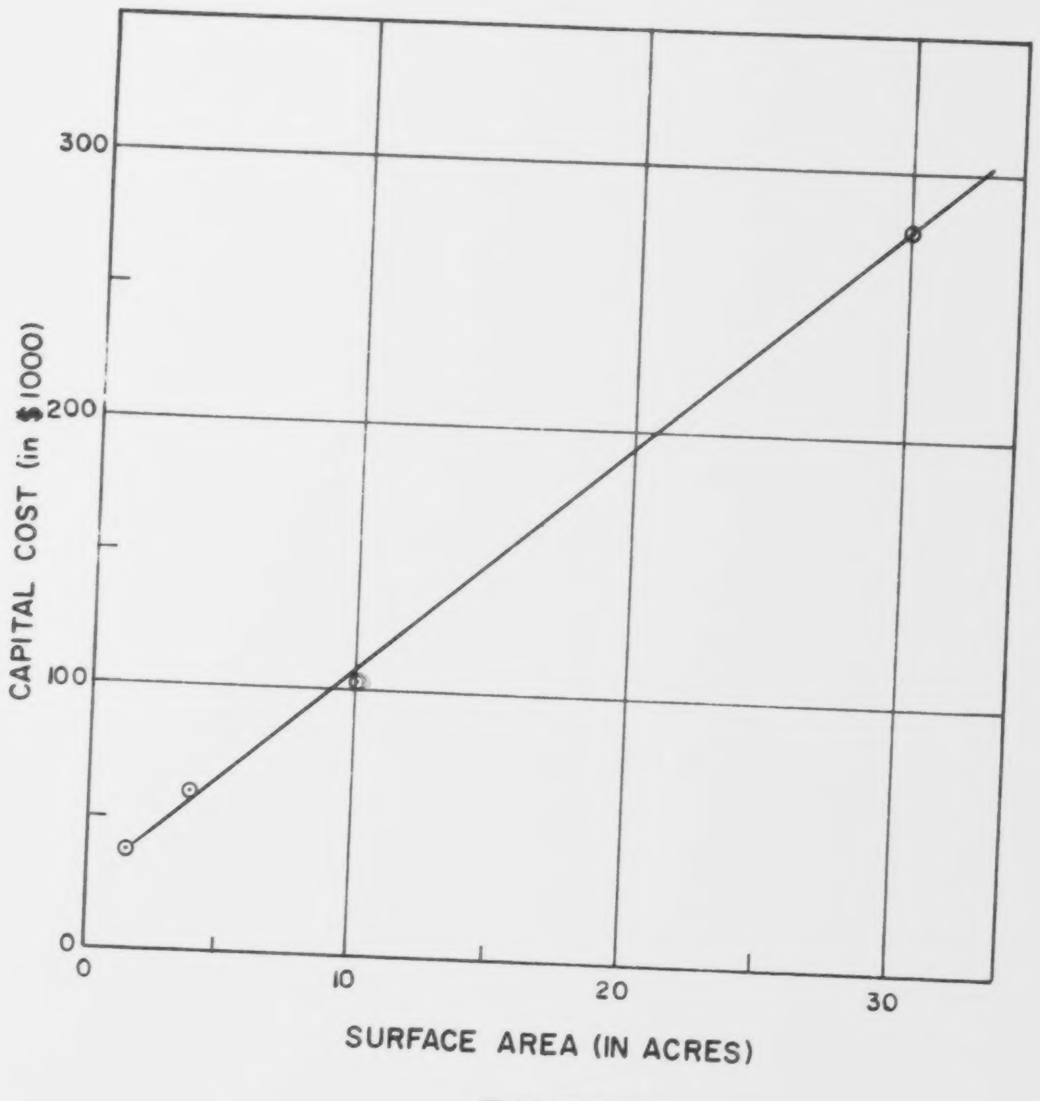


FIGURE 34
CAPITAL COST RELATIONSHIP FOR
LAGOONS REF. (4)

(a) temperature range
wet bulb temp 77° (Figure 19, Ref. 17)
dry bulb temp 95° (Figure 75, Ref. 17)
(b) wind speed - 15 mph (Figure 73, Ref. 17)
(c) relative humidity - 45% (psychrometric chart Figure 69, Ref. 18)

(2) From Figure 31

Determine vapor pressures
water @ 140° = 5.8"
Atmosphere @ 95°F = 1.67 x .45 = .75
$\Delta e = 5.8 - .75 = 5.05$

From Figure 32 Evap. = 5.8"/day

(3) From Figure 33 @ 5.8"/day evap.
read acres/mgd = 6.8 acre/mgd
@ .1 mgd - require .68 acre

Controlled Discharge (19)

Example:

Industry flow @ 200 mgd 308 cfm
Conc @ 1000 TDS = Ci
Stream flow @ 1200 cfs (775 mgd) mean annual flow = SF
Conc @ 100 ppm TDS = Cs
Coefficient variation @
Allowable stream concentration 500 ppm TDS = Ca
Based upon concentration factor -
allowable ratio = $\frac{IF}{SF} = \frac{Ca-Cs}{Ci-Ca}$

or, $\frac{IF}{SF} = \frac{500-100}{1000-500} = \frac{400}{500} = .8$

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(17) Flow Products Co., ibid

(18) Himelblau, D. M., "Basic Principles and Calculations in Chemical Engineering," Prentice Hall, Inc., England, New Jersey, 1967.

(19) Industrial Waste Guide on Thermal Pollution, U.S. Department of the Interior, FWPCA, Pacific Northwest Laboratory, Corvallis, Oregon, September, 1968.

∴ @ any time, industrial flow can be 80% of stream flow or, stream flow must be 125% waste flow

From flow duration curve (USGS)

(1) determine 84% occurrence value and 16% occurrence value
(2) calculate average ratio between these values and 50% occurrence value (Mode); this is Sigma (G) or standard geometric deviation.
(3) Determine coefficient of variation = $\frac{\text{sigma}}{\text{mode}}$

(refer to fraction of flow duration curve)

Example - 50% value - 1200 cfm

85% value - 7100 cfm
16% value - 280 cfm
$= \frac{7100}{1200} = 5.9 \quad \frac{1200}{280} = 4.3$, G Avg = 5.1
plotting geometric normal distribution
low (16%) @ 1200 ÷ 5.1 = 234 high (84%) @ 1200 x 5.1 = 6120

Coef of variation = $\frac{280}{1200} = .233$
or
$\frac{1200}{7100} = .17$
average = $\frac{.23 + .17}{2} = .20$

Entering draft/storage @ ratio industry flow to stream flow
IF/SF = 200/775 = .257

and cost of variability @ .25
Storage factor = .063 MAG
.063 x 775 mgd = 488 MG

Storage required
488 mgd x 365 days = 17,800 MG or 89 days

(4) from flow duration curve, flow of 318 cfm would be exceeded approximately 80% of the time
(5) allowing for dilution factor storage must be minimal by 25% or 17,800 mg x 125% = 22,300 MG

Note: No consideration of rainfall and evaporation has been made; each individual application should consider these factors separately.

Cooling Ponds

Temperature drop through a pond

(1) $To = (Ti-E)e^{-a'} + E$

where

To = outlet temperature °F

Ti = inlet temperature °F

(2) $a' = \frac{KA}{pCpQi}$

where

a' - decay e

K = energy exchange coef. (BTU ft^{-2} day^{-1})

A = pond area (ft^2)

P = water density (62.4# ft^{-3})

Cp = specific heat function (1BTU lb^{-1} $°F^{-1}$)

Qi = influent flow (ft^3 day^{-1})

E = equilibrium

Solving for $K = 157 + (0.26 + B)(bW)$

where

W = wind speed in mph

b = experimental evaporation coef.

B = proportionality coefficient

from E(°F)	B($mmHg^{-1}$)
50-60	0.405
60-70	0.555
70-80	0.744
80-90	0.990

Example

Assume $b = 12$

$K = 118$

$To = 80°F$

$E = 769$ °F

from eq. (1)

$80 = (93-769)e^{-a'} + 76.9$

$e^{-a'} = 0.193$

$a' = 1.65$

Eq. (2)

$$a' = \frac{118A}{(62.4)(1)(1500)(24)(3600)}$$

$a' = (1.46 \times 10^{-8})\ A = 1.65$

$A = 11.3 \times 10^7\ ft^2$

$A = 2590$ acres

COOLING TOWERS

Parameter affecting cooling tower costs are (Ref. 20)
(1) Wet bulb temperature - WBT
(2) Approach (CWT-WBT) = A
(3) Range (HWT-CWT) = R

where:
CWT is cooled water temperature
HWT is hot water temperature °F
WBT is web bulb temperature

Example:
An industry is located on a stream having an average dry weather flow of 1 cfm and a dry weather temperature averaging 70°F. Industrial discharge totals 400 gpm at 110°F. Local regulations limit temperature rise to 10°F.

By dilution alone, allowable discharge temperature can be computed by the relationship:

$$TM = \frac{Ti\ Qi + Ts\ Qs}{Qi + Qs} \quad \text{where}$$

or,

$$Ti = \frac{Tm\ (Qi + Qs) - TsQs}{Qi}$$

so, allowable discharge temp.

$$Ti = \frac{80(400 + 450) - 70\ (450)}{400} = 91°$$

and the cooling tower must lower the water temperature from 110°F to 91°F, or a range of approximately 20°. From local data (U.S. Weather Bureau) the average wet bulb temperature is 70° giving an approach of approximately 20°

Entering Figure 35 @ range of 20°, approach of 20°, and WBT of 70° - the relative rating factor of .8.

Using a cost factor of $10.00 per gpm (Ref. 20 + cost index increase)

The capital cost in 1000 x 400 gpm x .8 = $3,200

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(20) Cootner, P. H., Lof, Go. O., "Water Demand for Stream Electric Generation," John Hopkins Press, Baltimore, Maryland, 1965, p. 69.

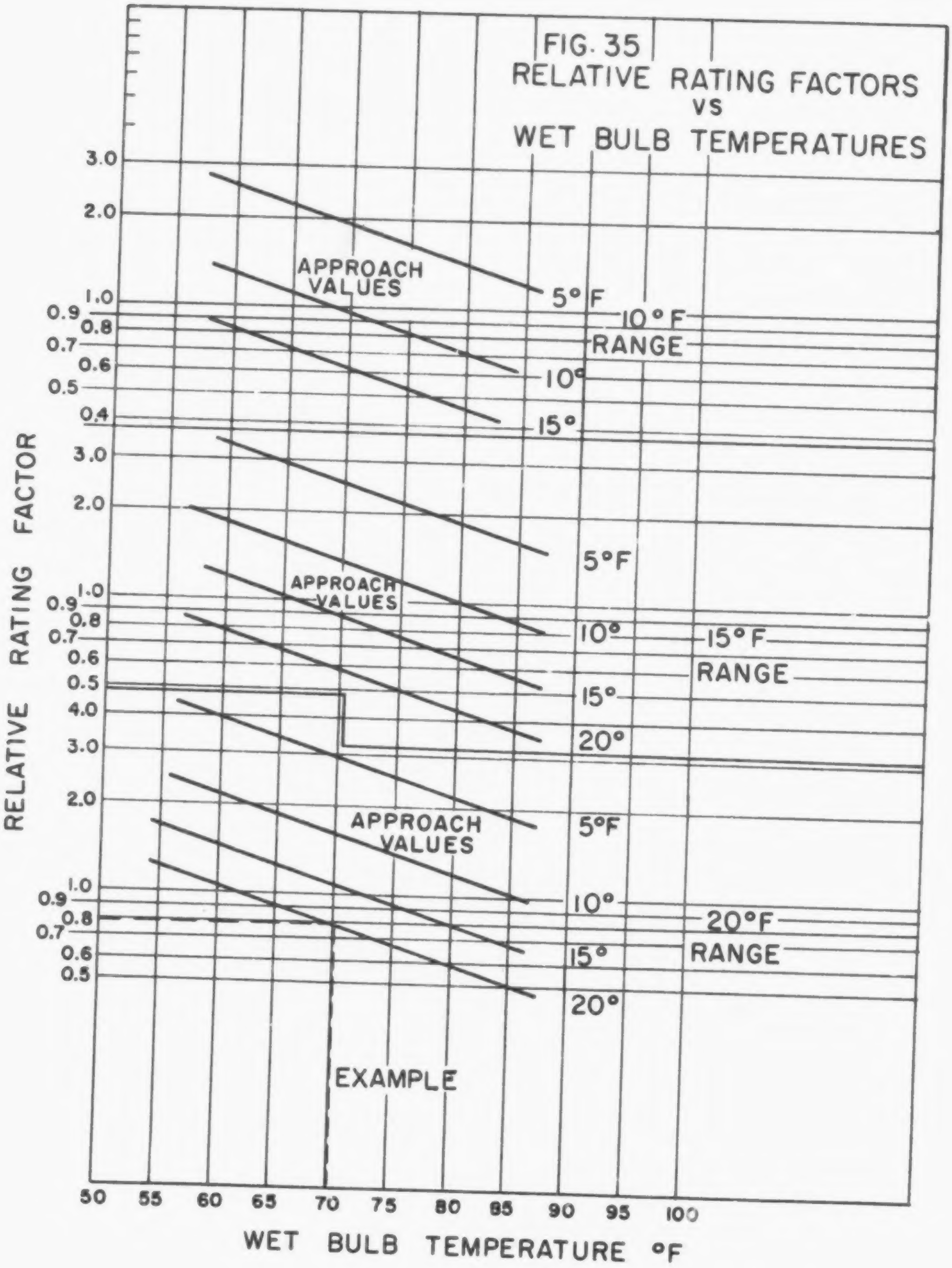

FIG. 35
RELATIVE RATING FACTORS
VS
WET BULB TEMPERATURES

Operating Cost

Cooling tower operating costs
Losses = 0.00112 R
Chemical = $.033\ Y + \frac{17}{C}$
Acquisition = Wa
Power = (0.14K + 0.005A)p

where:
R = range, °F
Y = alkalinity, ppm $CaCO_3$
C = concentration factor
Wa = cost of water/1000 gal.
K = Relative factor
P = Power costs in ¢/KWH
A = pumping head in

Total operating costs - (¢/1000 gal) when C=1, assuming Wa=10¢/1000 gal, power @ 1¢/KWH and allowing 0.5 KWH consumption for lifting 1000 gallon 100 feet (approximatey 85% efficiency).

Operating Cost = 0.00112 R (.033 Y + 17) + 10 + (.14K + .005A)

Example using graph in Figure 36:

Cooling tower operating under @ 20° range with a relative rating factor of 1.0, alkalinity of 1000, and assuming 100 foot operating head, cost/1000 gal= 2¢, assume 100,000 gpd flow, then operating cost - 2¢ x 100 = $200/day.

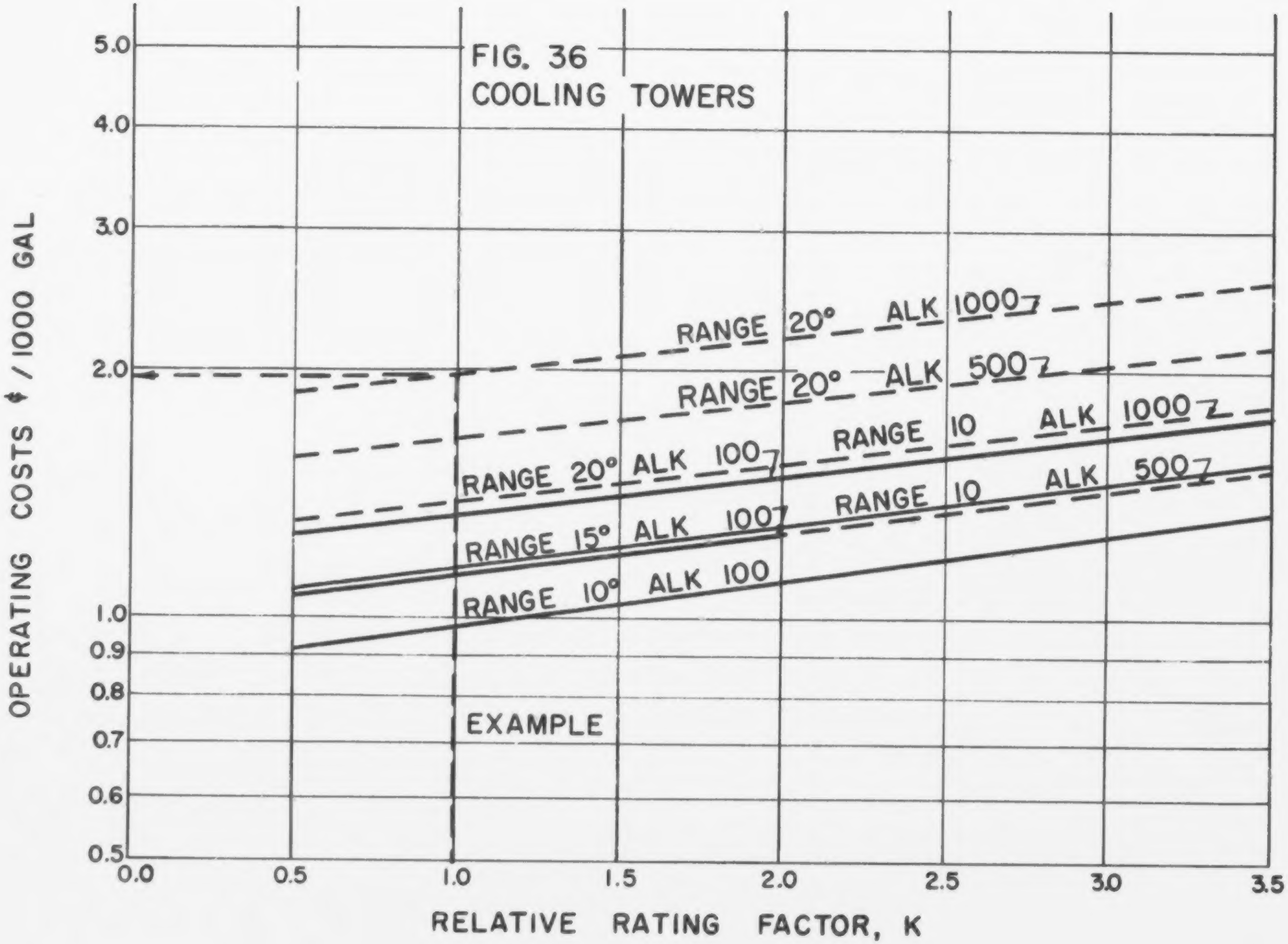

FIG. 36
COOLING TOWERS

APPENDIX F

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